Hearing Standards for Selection of Entry-Level Correctional Officers

State of California

California Department of Corrections and Rehabilitation

Prepared by Corrections Standards Authority, 2011

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The Corrections Standards Authority

The Corrections Standards Authority is a division of the California Department of Corrections and Rehabilitation.The role of the Corrections Standards Authority in developing selection standards is set forth in the California Penal Code, specifically Sections 13601-13603. These laws mandate the Corrections Standards Authority to develop, approve and monitor selection and training standards for state Correctional Officers who work in the state's prison system.

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The Correctional Officer position

Correctional Officer job description

The following are excerpts from the Department of Personnel Administration Job Description, Minimum Qualifications and Typical Tasks, for the Correctional Officer position pertinent to the research described in this report.

"In carrying out the primary duty of public protection, the Correctional Officer class performs duties that vary among institutions and among designated posts within an institution due to varying security levels of inmates, design of correctional facilities, geographical location, watch assignment, and the number of inmates. Assignments for this class include duty in towers, housing units, reception centers, kitchens, outside crew supervision, search and escort, control booths, yard, gun posts, and transportation."

The Correctional Officer class *"…disarms, subdues and applies restraints to an inmate; runs to the scene of an emergency; supervises the conduct of inmates or parolees in housing units, during meals and bathing, at recreation, in classrooms, and on work and other assignments, and escorts them to and from activities; stands watch on an armed post or patrols grounds, quarters, perimeter security walls and fences, or shops…"*

"…defends self against an inmate armed with a weapon; listens for unusual sounds that may indicate illegal activity or disturbances…"

Please see Appendix A for the complete Department of Personnel Administration Job Description.

Single personnel classification

The Correctional Officer position is a single personnel classification. Officers are assigned or transferred as needed throughout the state and must be qualified to perform the full range of duties at any prison in California. Thus, the hearing standards for Correctional Officers must ensure that they can perform all duties at any prison.

Entry-level standard

The hearing standard is designed to be used to select applicants for the entry-level position.

Executive summary

This report describes research conducted by the Corrections Standards Authority to establish hearing standards for the selection of Correctional Officers who work for the California Department of Corrections and Rehabilitation (CDCR).

The standard emanating from this research applies to entry-level applicants for the Correctional Officer position. Individuals in this position are responsible for the care, custody and control of 160,000 inmates incarcerated in the state's 33 prisons.

Public protection and safety issues are significant for this position. Correctional Officers must prevent escape, quell riots, and protect the public and other custody personnel. Personal safety issues are considerable, and Correctional Officers are at risk of assault and even death.

The research described in this report shows that the Correctional Officer's job requires a high degree of physical and sensory abilities, including hearing. Correctional Officers are required to react and respond appropriately in time-sensitive situations using good professional judgment, lethal and non-lethal tools, and requisite physical and sensory abilities. Any hesitancy, reluctance, or inability to fully engage in a critical and potentially life-threatening situation based on an inability to hear could set in motion a series of events that could have substantial, even fatal, consequences.

The hearing standard for entry-level Correctional Officers was last updated in 1992, nearly two decades ago. To establish a hearing standard in 2011, CSA took the following actions:

- Supplemented existing job analyses with research that supplies additional information on hearing-critical job functions and activities that represent the current job.
- Incorporated scientific advances in research methods related to hearing abilities to produce a standard supported by strong empirical evidence.
- Measured and recorded background noise in a representative sample of prisons.
- Utilized advanced, standardized statistical methods for analyzing workplace noise environments to determine their impact on hearing-critical job functions.
- Incorporated recent methods to test hearing ability, especially as they relate to speech communication in quiet and in noisy environments.
- Supplemented the methods used to test hearing ability so that individuals with auditory prostheses (hearing aids, cochlear implants, and other devices) can be tested.

Highlights of the research findings are as follows:

- Correctional Officers must rely on effective speech communication to perform hearing-critical job functions such as responding to a variety of disturbances and emergencies, communicating orally with inmates or other Correctional Officers, and coordinating movements with other Correctional Officers.
- Speech communication is a frequently used and demanding job function in the prison environment.

- More than 28% of the cues for detecting incidents and emergencies are exclusively based on hearing, and another 23% involve hearing as a critical component.
- Correctional Officers must defend themselves while wearing protective headgear and other protective equipment during certain adversarial encounters such as cell extractions and riots. This protective headgear may interfere with the use of auditory prostheses.
- Hearing-critical functions are performed during all shifts.
- Background noise levels in prison environments where Correctional Officers perform hearing-critical job functions are measured in decibels, abbreviated dB (A). The measurements in a variety of locations within the prisons ranged from almost 90 dB(A) at its loudest to 62 dB(A) at its softest, with average values between about 70 dB(A)—this would be subjectively characterized as “loud”—and 85 dB(A) —this would be subjectively characterized as “exceptionally loud.”
- The likelihood of effective speech communication in prison noise environments for a person with normal hearing ranges from less than 20% when normal vocal effort is used up to 100% when shouted effort is used.
- Even small reductions in effective speech communication caused by hearing impairment can have substantial adverse consequences because effective communication is already made difficult by the background noise levels in prisons.
- Measures of speech recognition in noise are better predictors of functional hearing abilities used by Correctional Officers to perform hearing-critical job functions than traditional measures based on pure-tone audiometry.

The most appropriate and valid test for evaluating the functional hearing ability of applicants for the Correctional Officer position is the Hearing in Noise Test (HINT). The HINT provides better objective prediction of an applicant’s ability to perform hearing-critical job functions than do measures of hearing sensitivity obtained with other methods such as pure-tone audiometry.

The new standard is based on measures of speech recognition in quiet and in a background noise condition that is representative of the levels existent in the Correctional Officer’s workplace. The screening criterion in quiet is 27 dB (A) or less. In noise at 75 dB (A) the screening criterion is 71 dB (A) or less, corresponding to a signal/noise ratio of -4.0 dB or lower.

Research strategy

The goal of this research was to define valid hearing screening measures to evaluate applicants for Correctional Officers positions. The strategy to develop these screening measures consisted of four major elements:

1) Identification of hearing-critical job functions Correctional Officers perform;

2) Determination of functional hearing abilities important in the performance of these functions (e.g., speech comprehension, sound detection and recognition, sound localization, etc.);

3) Assessment of the impact of the sound environment, especially background noise levels, on the performance of these functions; and,

4) Selection of valid and reliable screening tests and protocols to predict the necessary hearing abilities.

The research strategy was designed as a sequence of steps, with each step establishing the foundation for the next. This approach linked the important hearing-critical job functions Correctional Officers perform to the screening measures and screening criteria of hearing ability.

Early in the research it became clear that speech communication was an important functional hearing ability of a Correctional Officer. It was also evident that this speech communication often took place in noisy environments. These observations refined the strategy to determine whether the ability to communicate with speech in noisy environments is a sufficiently important functional hearing ability to warrant its use as a screening measure. If so, the hearing standard could be focused primarily on speech communication.

There were several advantages to adopting such focus. First, there are standardized metrics for quantifying an individual's ability to understand speech in quiet and in noise (American National Standards Institute, 2007). These metrics have recently been extended and validated for use with every-day background noise (Rhebergen & Versfeld, 2005; Rhebergen et al., 2006, 2008), such as the workplace noise environments encountered by Correctional Officers. Second, speech communication in quiet and noise is perhaps the most demanding and challenging of all functional hearing abilities. If applicants can hear well enough to communicate effectively with speech in quiet and in noise, then it is reasonable to assume they can also hear non-speech sounds in these environments.

The remainder of this section describes each research step, emphasizing the link between the hearing-critical job functions and the screening criteria.

Research steps

Step 1: Review existing job analyses

The research began by reviewing existing job analyses for the Correctional Officer position. This step did not allow specific hearing-critical job functions to be identified because the job analysis was not designed to provide information needed to establish medical standards. Rather, this review provided the context for subsequent research steps that focused on specific hearing-critical job functions.

Step 2: Analyze hearing-critical job functions from incident reports

Research staff collected written *incident reports* (documentation of unusual or unlawful activities and events) from all of the prisons throughout the state. The incident reports provided information about important hearing-critical job functions related directly to the safety and security of Correctional Officers.

These reports were analyzed to identify hearing-critical job functions that occurred as Correctional Officers became aware of incidents and responded to them. Research staff analyzed each report for type of incident, time and location of incident, means of incident detection (hearing, vision, hearing and vision), and primary functional hearing ability used. These analyses revealed that most incidents were detected by hearing alone or by hearing in combination with vision. Detection often involved hearing either speech or non-speech sounds. However, the response to the incident almost always required communication with speech.

These analyses provided evidence that detecting and responding to incidents are hearing-critical job functions and that speech communication is an important, and at times essential, functional hearing ability used on the job.

Step 3: Identify hearing-critical job functions through interviews with Correctional Officers

The research team conducted semi-structured interviews with experienced Correctional Officers who served as *subject matter experts* to further identify hearing-critical job functions. Participants in these interviews were sampled from throughout the state prison system, and included both line officers and supervisory personnel.

Participants in the interviews were first asked to describe the hearing-related activities that took place during a routine day across all work shifts. A semi-structured protocol was implemented to capture these data in terms of hearing-critical job functions. Following descriptions of the routine day, officers were asked to describe non-routine activities and incidents that they had experienced with respect to their need to hear sounds and to communicate with speech. These activities and incidents included events such as inmates assaulting inmates, inmates assaulting Correctional Officers, medical emergencies, and suicides or attempted suicides. The same semi-structured protocol was then used to obtain information about hearing involved in these non-routine activities and incidents.

The interviews provided substantial detailed information about the functional hearing abilities required to perform hearing-critical job functions. One of the most important pieces of evidence to emerge from these interviews was that hearing-critical job functions often take place in high background noise levels. The ability to communicate accurately with speech in the presence of high background noise was again identified as an essential functional hearing ability. The subject matter experts described several ways by which they attempted to achieve accurate and effective speech communication in loud background noise such as the frequent use of a loud or shouted voice, repetition, and reliance on close communication distances.

The interviews also allowed identification of the locations within the prisons and the times throughout the day where hearing-critical job functions involving speech communication are most likely to take place. This information served as an important basis for planning the visits to prisons so research staff could observe hearing-critical job functions performed in the appropriate locations and at the appropriate times to measure and record background noise environments for later analyses.

Step 4: Determine the primary functional ability to examine

This step consisted of the synthesis of the evidence gathered in the two preceding steps (analysis of the incident reports and interview data). Findings from these steps repeatedly and consistently underscored the importance of accurate and effective speech communication in the performance of many hearing-critical job functions. Evidence for this was seen in the detection and response to incidents, in the performance of routine daily activities, and in the performance of non-routine daily activities. The data also revealed that many hearing-critical job functions involving speech communication take place in the presence of high level background noise, requiring Correctional Officers to speak loudly or shout, to repeat their communication, and to rely on short communication distances.

As a result of these considerations, the ability to communicate with speech in moderate-high level background noise was identified as a primary functional hearing ability in the performance of hearing-critical job functions by Correctional Officers. Having identified the importance of speech communication in noise as a major functional hearing ability, the subsequent research focused primarily on this ability. This focus was justified because speech communication is generally a more demanding functional hearing ability than detection and recognition of non-speech sounds, and thus the ability to understand speech communication in quiet and noise implies the ability to hear non-speech sounds as well in such environments. These considerations guided the remaining steps in the research process.

Step 5: Select a representative sample of prisons for on-site observations and noise measurements

The most important aspects of these prisons that affect noise levels are the design and construction age of the facility. These were the primary aspects used in selection of the prisons to be visited. Other aspects used in selection included geographical region within the state, security levels of housing within each prison, and gender of the inmates. A total of seven prisons were selected to form a representative sample to be visited for on-site observation and recordings. Appendix L provides background information on the State prison system used in the selection of the sample.

Step 6: Select locations and times within each prison where hearing-critical job functions occur

Building on information from the incident report analysis and the interviews, research staff were able to set priorities for the times and locations where noise levels should be measured. Before measurements were recorded at each prison Correctional Officers and their supervisors were interviewed so that they could provide additional data specific to their facility regarding times and locations for the recordings to be made. In this manner, the rationale and evidence supporting the selection of each noise environment was explicitly linked to all of the preceding steps in the research strategy.

Step 7: Record and measure background noise environments where hearing-critical job functions occur

Recordings of noise environments within the facilities enabled research staff to objectively characterize the effects of the noise on speech communication. Recently published research has demonstrated the validity of new metrics for achieving these objective characterizations (Giguere et al., 2008, 2010; Laroche et al., 2003, 2005, 2008). These metrics require that the fluctuating frequencies and levels of each noise environment be accurately captured for subsequent standardized analyses (Rhebergen & Versfeld, 2005; Rhebergen et al., 2006, 2008). To perform these analyses, the research team made high quality calibrated digital sound recordings several minutes in length at each sampled prison at specified times and locations. The research team also maintained detailed logs describing the conditions for each recording.

Step 8: Analyze noise recordings

Each noise recording was analyzed according to the procedures and methods described in the recent publications describing and validating the *Extended Speech Intelligibility Index* (ESII) (Rhebergen & Versfeld, 2005; Rhebergen et al., 2006, 2008). The ESII is based on the calculations and parameters from the *Speech Intelligibility Index* (SII) standard (American National Standards Institute, 2007). These standardized calculations, when applied to the ESII, make it possible to estimate the likelihood of accurate and effective speech communication in each background noise environment for *otologically normal* individuals. The results of these analyses provide objective evidence about the likelihood that otologically normal Correctional Officers can perform hearing-critical job functions that require accurate and effective speech communication in each of the selected noise environments.

Step 9: Estimate the likelihood of effective speech communication in prison noise environments

The overall impact of hearing impairment can be determined by assessing the impact of hearing impairment on each hearing-critical job function and then forming an overall assessment comprised of the weighted combination of the assessments for each hearing-critical job function. The research team assigned weights, based on these assessments, to the noise analyses from the locations where each hearing-critical job function was performed.

The analyses of the noise recordings provided objective evidence about the ability of otologically normal Correctional Officers to achieve accurate and effective speech communication in each noise environment. However, these analyses do not provide evidence of the overall likelihood of accurate and effective speech communication throughout the typical day of a Correctional Officer. To obtain this evidence it was necessary to determine the proportion of time a Correctional Officer was likely to spend in each noise environment as well as the importance of the hearing-critical job functions involving speech communication that are performed in each noise environment. With this evidence it was possible to form a weighted combination of the results from the ESII calculation for each noise environment that represents the overall likelihood of effective speech communication throughout the entire typical day of an otologically normal Correctional Officer, including routine activities, non-routine activities, and incidents. The weighting of each noise environment was based on the analyses of the incident reports and the semi-structured interviews.

Given the overall likelihood of effective speech communication throughout the entire day for an otologically normal Correctional Officer, it was possible to introduce the effects of hearing impairment into the ESII calculations. Research staff then made quantitative estimates of the impact of this impairment on the likelihood of effective speech communication during the performance of hearing-critical job functions by Correctional Officers. The process for obtaining these estimates is described in the next step.

Step 10: Determine the impact of hearing impairment on the likelihood of effective speech communication

The weighted combination of ESII analyses that yields the overall likelihood of effective speech communication throughout an entire typical day refers only to otologically normal individuals (American National Standards Institute, 2007). However, the hearing standard must establish the amount of hearing impairment in otologically abnormal individuals that is acceptable in applicants for the job of Correctional Officer. Thus, it was necessary to determine the effects of hearing impairment on this measure of speech communication ability. Once evidence was collected about these effects, it was possible to use appropriate measures of hearing impairment to establish objective hearing screening criteria.

There are two aspects of hearing impairment that affect functional hearing abilities, such as speech communication in quiet and noisy environments (e.g., Plomp, 1978, 1986; Soli, 2003). It is important to determine how each aspect affects the likelihood of effective speech communication throughout the typical day of a Correctional Officer.

The first aspect of hearing impairment that can affect functional hearing ability is *audibility*, the inability to hear soft speech or other sounds—as measured with traditional *pure tone audiometry* (Plomp, 1978, 1986; Soli, 2003). This measure of hearing impairment has traditionally found widespread and effective use in clinical diagnoses of hearing impairment, establishment of a baseline for documentation of temporary threshold shifts after occupational noise exposure, and in disability determination.

The SII standard, as well as the ESII, which relies on the SII standard (American National Standards Institute, 2007), provides explicit methods for incorporating reduced audibility into estimates of the likelihood of effective speech communication for each noise environment. These methods were employed to determine whether pure-tone audiometry, which only estimates audibility, is an accurate predictor of the likelihood of accurate and effective speech communication throughout the typical day of a Correctional Officer.

The second aspect of hearing impairment that can affect functional hearing ability is *distortion*¸ the requirement for a larger *signal-to-noise ratio (SNR)* to understand speech when both the speech and the background noise are audible (Plomp, 1978, 1986; Soli, 2003). This measure of hearing impairment has recently been used for some types of clinical diagnosis of hearing impairment and for occupational hearing screening where functional hearing abilities are at issue (Laroche et al., 2003, 2005, 2008; Goldberg, 2001).

Neither the SII standard nor the ESII calculations provides an explicit means of incorporating the distortion aspect of hearing impairment into the screening process. However, recent publications (Houtgast & Festen, 2008; Giguere et al., 2010) have shown that relatively simple measures of the *speech reception threshold in noise*, expressed as the SNR at the threshold of speech understanding (*speech intelligibility*), can be used to determine the effects of distortion on the ability to understand speech in noisy environments.

Analyses of the effects of audibility and distortion aspects of hearing impairment on effective speech communication throughout the typical day of a Correctional Officer provided evidence that the distortion aspect of hearing impairment is more important than audibility in screening the functional hearing abilities of applicants for Correctional Officer jobs. This evidence was used to establish the screening materials, screening protocol, and screening criteria using measures of the speech reception threshold in quiet and in noise.

Step 11: Specify screening materials for the hearing standard

The evidence from the preceding step indicated that each aspect of the hearing standard, the screening materials, the protocol, and the criteria, should be based on measures of the ability to communicate with speech, such as the speech reception threshold (SRT), in quiet and in noise. The SRT in quiet assesses the effects of hearing loss on audibility, and the SRT in audible noise assesses the effects of hearing loss on distortion. Since people hear with both ears, these measures should be obtained using *binaural* presentation of the speech and noise. When the SRT is measured binaurally in noise, the spatial location of the speech and the noise have a substantial effect on the ability to understand speech in noise (Nilsson et al., 1994; Plomp & Mimpen, 1981). When the speech and noise are spatially separated, as often happens in daily life, the SRT can be much lower and, consequently, speech intelligibility is substantially better.

This evidence implies that SRTs measured in noise must include test conditions where the speech and noise are spatially separated. Since such conditions are difficult to create reliably with loudspeakers in a *sound room*, all SRT measures should be taken under headphones. Finally, the performance of otologically normal individuals on each SRT measure, in other words the *norms* for each measure, must be known, since the ESII calculations are applicable only to such individuals. Hearing impairment can reduce audibility, causing SRTs in quiet to be poorer than the norms. Hearing impairment can also increase distortion, causing SRTs in noise to be poorer than the norms. Thus, elevation of SRTs provides evidence of reduced ability to communicate with speech in quiet and/or in noise.

The Hearing In Noise Test (HINT) (Nilsson et al., 1994; Vermiglio, 2008; Soli & Wong, 2008) was chosen to provide the screening materials. The HINT satisfies all of the screening requirements described above, and it is currently used for screening applicants and incumbents for a variety of public safety jobs with hearing-critical job functions (Goldberg, 2001; Laroche et al., 2003, 2005, 2008; Giguere et al., 2008, 2010).

Step 12: Specify screening protocol and screening criteria for the hearing standard

Two different hearing screening criteria are specified. The first is based on the SRT in quiet as measured with the HINT. This criterion is specified to ensure that applicants with reduced audibility caused by hearing impairment can hear and understand soft or whispered speech.

The second is based on a composite of three SRTs measured in noise. This criterion is specified to ensure that applicants with increased distortion caused by hearing impairment can hear and understand speech in the noise environments where Correctional Officers routinely perform hearing-critical job functions.

Step 13: Evaluate use of auditory prostheses by Correctional Officers

Hearing impaired applicants for the job of Correctional Officer may require the use of one or two auditory prostheses, such as hearing aids, to meet the screening criteria specified in the hearing standard. If a hearing impaired applicant is able to meet these criteria with their prostheses, it will be necessary for this individual to wear and use their prostheses at all times on the job. This requirement raised the question of whether there are aspects of the job, or job requirements, which could not be performed while using auditory prostheses.

To address this issue, the research team conducted additional interviews with subject matter experts. These interviews revealed that Correctional Officers must at times wear protective equipment, such as riot helmets, that may interfere with the usability of auditory prostheses. If a Correctional Officer is required to wear auditory prostheses at all times, including while wearing a protective helmet, evidence that the prostheses function properly under the helmet is required as part of the hearing screening protocol. Of particular concern was the question of whether hearings aids would function properly when worn under a riot helmet that entirely covers each ear.

Research staff surveyed experts from the hearing aid industry to determine whether hearing aids would function properly under riot helmets. The experts provided consistent responses that proper function could not be ensured under such conditions. This evidence provided the rationale for the inclusion of additional measures in the screening protocol for applicants who must use auditory prostheses to meet the hearing standard.

Step 14: Supplement the screening protocol for individuals with auditory prostheses

The final step was to adapt the screening protocol for applicants who use auditory prostheses such as hearing aids to meet one or both of the screening criteria. The evidence that protective headgear such as riot helmets can interfere with the proper function of hearing aids, and possibly other prostheses as well, necessitated adaptation of the protocol to verify that the prostheses would function properly when worn under a riot helmet. Thus, the screening protocol specifies a sound field administration of the HINT as well as direct observation of the functionality of the applicant's prostheses when worn under a riot helmet.

The chart in Figure 1displays graphically the relationships among each of the steps comprising the research strategy.

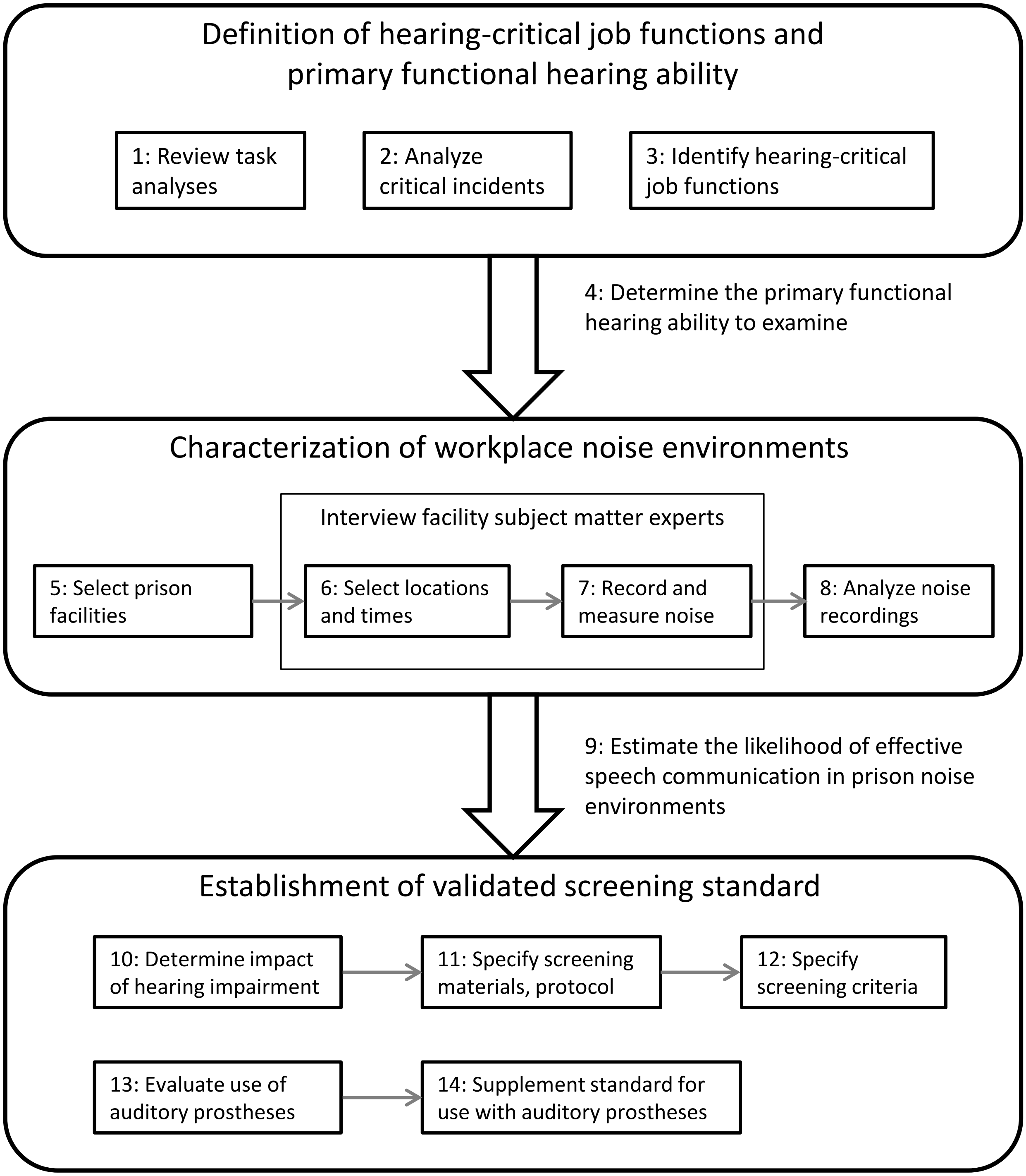


Figure 1. Graphical summary of 14-step research strategy.

Existing job analysis review

The first step in the research strategy consisted of a review of the existing job analyses.

Background and rationale

Job analyses identify all the tasks and equipment use that comprise a particular job or class of jobs. Such an analysis of the Correctional Officer job was completed in 2007. Review of this analysis served as a starting point for the identification of the *hearing-critical job functions* performed by Correctional Officers. Hearing-critical job functions are defined as those functions where hearing is absolutely essential, and no other sense modality or behavioral adaptation can be used to supplement hearing to perform the function (e.g., Soli, 2003; Laroche et al., 2003; Giguere et al., 2008). A simple example of a hearing-critical job function is use of a telephone or radio to communicate with speech.

This review did not allow specific hearing-critical job functions to be identified, since the level of detail in the job analysis was not originally intended for use in the establishment of medical standards. The review did, however, provide an appropriate context and starting point for the subsequent analyses.

Methodology

The research team reviewed the job analysis to identify as many tasks as possible where hearing was required. Although the term "hearing" was not often used in the description of each task, the use of other terms, such as "listen," "communicate orally," etc., made it possible to identify tasks that might include hearing-critical job functions. The job analysis also identified equipment Correctional Officers use that might have implications for hearing-critical job functions.

Results

The research team found that a large number of tasks clearly required Correctional Officers to hear information in their environment. For example, the following are four of the many tasks implying that Correctional Officers need to hear and understand the spoken words of another person. These tasks were rated in the job analysis as being performed frequently and as being critical to the performance of the job.

- Respond to an auditory message (by an inmate, another Correctional Officer, a radio, or a general alarm) to move to the scene of a disturbance or emergency.
- Question inmates to obtain information.
- Communicate orally.
- Answer phone calls.

Other tasks, such as "Listen for unusual sounds that may indicate illegal activity or disturbances such as whispering, scuffling, or rattling of chain link fence" indicated that Correctional Officers also need to hear non-speech sounds. Still other tasks, such as "Render aid to injured inmates and other correctional staff" and "Supervise inmates in housing units, during meals, and bathing" suggested that speech communication would likely be involved in the ordinary course of performing those tasks.

The 2007 job analysis also identified equipment that was used frequently by Correctional Officers during the performance of hearing-critical tasks. A sample of items rated as being used frequently and being critical for the position is as follows:

- Body armor (e.g., protective vests)
- Mace, tear gas or OC spray
- Personal alarm system
- Gas mask or self-contained breathing apparatus
- Telephone
- Radio

Discussion

The review of the job analysis revealed a number of tasks that allowed research staff to identify some hearing-critical job functions. However, the analysis did not contain adequate detail to determine the parameters of these hearing-critical functions such as the proximity of the sound source, the vocal effort involved in hearing the speech or sound, or the level of background noise present that are needed to define specific functional hearing abilities.

Incident report analysis

The second step in the research strategy was to analyze hearing-critical job functions from incident reports sampled from throughout the State prison system.

Background and rationale

Incident reports are prepared by Correctional Officers to document unusual or unlawful activities and events that have occurred within the prison. These activities and events often involve responses to emergency situations. An analysis of these reports can, at least indirectly and often directly, reveal those hearing-critical job functions that were performed in response to incidents and the interventions needed to resolve them.

Examples of activities documented in incident reports include the following:

- possession of contraband,
- altercations between inmates,
- assaults on Correctional Officers and other prison staff,
- disruptive or unusual inmate behavior,
- attempted suicides, and
- medical emergencies.

Virtually all incidents require the involvement of Correctional Officers; furthermore, it is almost always the Correctional Officer who determined that an incident was taking place and whose intervention was needed to resolve it.

Incident reports include information concerning the detection of the incident, where and when it took place, what transpired as it unfolded, and how it was resolved. The research team analyzed a sample of incident reports to identify job functions that are hearing-critical as well as the locations within the facility and the time of day associated with each incident. Examples of incident reports are provided in Appendix B.

Methodology

The research team collected a sample of incidents from a representative group of facilities. The team obtained reports from all 33 state facilities, thus encompassing a range of facility types, sizes, capacities, inmate populations, gender, physical structures, and geographic locations. For the reports to be representative of an entire facility day, five reports were requested from each shift or watch for a total of 15 reports. Research staff logged and coded the incident reports to track the source of the information.

Sampling of incident reports

With 33 facilities providing 15 or more reports, approximately 500 reports were accumulated. Each report was read by two research team members in the process of performing a content analysis. To ensure the reliability of the coding schema, and because several pieces of information were coded, it was feasible to process only a subset of the reports given the available resources and time constraints. Over half of the reports were selected for analysis to ensure that all shifts and all facilities were represented. Because the Northern region of the state has fewer facilities compared to the Central and Southern regions of the state, a slightly smaller subset was chosen from the Northern facilities. In total, the research team analyzed 75 reports from the Northern region, 100 reports from the Central region, and 100 reports from the Southern region. Within each shift reports from each region were chosen randomly from the set of available reports.

Coding and categorization of incident reports

Research staff reviewed each report with respect to certain features or coding categories such as type of incident. When that category was encountered, the instance of the category (e.g., suicide attempt) was recorded. The purpose of coding features in the incident report analysis was to get a better sense of the general types of incidents and the hearing-critical job functions Correctional Officers perform when responding to incidents. Research staff also classified the incident reports according to whether the incident was initially detected by hearing, by vision, or by both hearing and vision.

“Vision only” meant that Correctional Officers knew an incident was occurring because they saw something. “Hearing only” meant that Correctional Officers knew an incident was occurring because they heard something. “Both vision and hearing” meant that Correctional Officers knew an incident was occurring because they simultaneously heard and saw something.

Results

The analyses of the coded incident reports revealed information about the frequency of each type of incident, the location where the incident occurred, the time of day and the watch when the incident occurred. Tabular summaries of these analyses are reported in Appendix C. Although this information provided substantial detail about the nature of incidents and when and where they occurred, it proved difficult to accurately identify from the contents of the reports those parameters of the hearing-critical job functions and the functional hearing abilities used to perform these functions.

Incidents were categorized into seven types: contraband, medical intervention, physical assaults involving two individuals, physical assaults involving three or more individuals, oppositional behavior, unusual or abhorrent behavior, and suicide or self-injury. Two additional general categories were also defined: miscellaneous and multiple elements (more than one category from the above list). Definitions and examples of each type of incident are given in Table 1.

Table 1. Categories of incident types used to classify incident reports

Incident Type	**Definition**
Contraband	Weapons, drugs, or any other unauthorized items (e.g., an extra blanket, extra socks, etc.)
Medical Intervention	Death, bleeding, collapse, seizure, physical trauma, unintentional self-injury; need for First Aid, CPR
Physical Assault/Battery/ Altercation One -on-One (2 People)	Physical altercations, assaults, or battery; does not include physical threats such as fist clenching, or injuries against self.
Physical Assault/Battery/ Altercation Group (3+ People)	Physical altercations, assaults, or battery among a group of three or more individuals; does not include physical threats such as fist clenching, or injuries against self.
Non-Assaultive/ Oppositional Behavior	Active verbal/vocal interaction, oppositional behavior, not following instructions, banging on walls with attempts to be disruptive, and non-assaultive threatening behaviors such as fist clenching. Recounts of vocal/verbal events, summaries, or third party accounts not considered here.
Unusual/ Abhorrent Behavior	Crying, indecent exposure, hallucinations, intoxication, altered emotional states, etc. Threats of suicide however, not included in this category.
Suicide, Suicide Threat, Suicide Attempt/ Self-Injury	Suicide, suicide threats, attempts or other instance of self-injury; banging head on wall or floor, punching/kicking walls or other inanimate objects (with intent to harm oneself). Unintentional self-injury not considered here.
Miscellaneous	Miscellaneous incidents including an escape or an attempted escape and reports from individuals who were not the first responders.
Multiple Elements	An incident that involves multiple elements or instances of the above categories.

Table 2 displays the percentage of the incidents where vision, hearing, or both vision and hearing alerted Correctional Officers that an incident was occurring. More than a quarter of the cues for detecting incidents were exclusively based on hearing, and another 23% involved hearing as a critical component. Thus, hearing was used in the detection of more than half the incidents. These results make it clear that hearing is a very important sensory ability for Correctional Officers.

Table 2. Sensory cues for incidents

Sensory Cue	Percentage
Vision only	48.4%
Hearing only	28.7%
Both vision and hearing	22.9%

Discussion

As was true for the job analysis, the incident reports were prepared for purposes other than those guiding research needed to establish valid hearing standards. Both sources of information were initially considered in conducting this research because they helped to establish the broader context for the job of Correctional Officer. However, neither provided sufficient details of the hearing-critical job activities and their specific context. Rather, research staff gathered relevant information about these hearing-critical job functions through semi-structured interviews with Correctional Officers, the next step in the research strategy.

Interviews with Correctional Officers

The third step in the research strategy was to identify hearing-critical job functions through semi-structured interviews with Correctional Officers who served as subject matter experts.

Background and rationale

The job analyses and the incident reports both revealed clearly the necessary and important role of hearing in the tasks that Correctional Officers perform on the job. However, to establish valid hearing standards it was necessary to identify and document the specific functional hearing abilities that Correctional Officers use to perform the hearing-critical job functions that are part of their routine and non-routine daily activities. This type of specific information was obtained through interviews with experienced Correctional Officers. These officers described in detail and responded to specifically designed questions about these job functions and related functional hearing abilities.

The research team selected the commonly used method of semi-structured interviews (e.g., Guion, 1998) to obtain this information. Research staff met with experienced Correctional Officers who have either performed the job for several years or who supervise such individuals. Such individuals are referred to as subject matter experts (SMEs). Small groups of SMEs were interviewed together, which allowed each SME to correct or enrich the information supplied by other SMEs. This method is not only time efficient, it also enables integration of SME responses (Brannick et al., 2007). Often, the group process allows information to surface that might not otherwise be obtained during individual interviews.

Methodology

The research team assembled three panels of Correctional Officers. Twelve officers representing prisons throughout the state were selected for these panels, four for each panel, based on their extensive knowledge of the job. Several of the Correctional Officers had worked in more than one facility and thus were familiar with a broad range of prison designs and inmate characteristics.

The SME panel meetings explored activities within facilities that involved hearing-critical job functions. The research team asked the SMEs a series of questions related to these functions to determine where and when they occurred and what they entailed. The SMEs responses and subsequent discussion provided details about each function and the hearing abilities used to perform the function.

The interview process was divided into two phases. The first phase focused on hearing-critical job functions that occur throughout a routine work day. The second phase addressed hearing-critical job functions that occur in response to incidents at any time during a shift.

Results from the first interview phase provided an overall picture of the functional hearing abilities used during a routine day and the job-related activities associated with them. This information was used later to construct a quantitative model that synthesized information about when and where the most important hearing-critical job functions occurred throughout the day. The results were also used to identify communication with speech, especially in noisy environments, as an extremely important functional hearing ability needed to perform these job-related activities throughout the day.

Likewise, results from the second interview phase provided information about the functional hearing abilities used in response to incidents. This information supplemented the findings from the incident reports and allowed the research team to determine the specific functional hearing abilities needed during responses to incidents. Again, the SMEs identified speech communication as essential in the course of performing the necessary and appropriate actions to control and resolve incidents.

The following is a detailed description of the methods used to conduct the semi-structured interviews for the routine day. Each SME was assigned a different four-hour time segment during the routine day. They were then asked to identify 5–6 hearing-related hearing job functions or tasks that a Correctional Officer might perform during that time segment. They were encouraged to construct a mental composite to represent the activities during that time period. This process was repeated for each time segment to characterize the entire routine day. Once the day had been reconstructed in this manner, the panel analyzed each identified job function or task to determine the functional hearing abilities used in performing the function or task.

For speech communication activities, SMEs were asked to indicate or describe:

- Vocal effort of the communication
- The degree to which the message was understood
- Whether the speech could be repeated

For non-speech sounds, SMEs were asked to indicate or describe:

- Whether the activity required detection, recognition, or localization

- The amplitude of the sound
- The characteristics of the sound (single burst, continuous, intermittent)

For all sounds, SMEs were asked to indicate or describe:

- The distance of the Correctional Officer from the sound source
- Whether the source was visible
- The level of the background noise
- The overall effort needed to hear the sound

The specific questions asked of the SMEs to obtain this information are reported in Appendix D.

After the review of a routine day, SMEs described incidents. Since incidents do not necessarily occur during a specific watch, the SMEs were simply asked to recall an incident that they had experienced that involved hearing. Once the SMEs related such an event to the group, they were asked when and where that incident had occurred, and whether the cue for the incident involved speech communication or other non-speech sounds. With this information in hand, the research team guided the SMEs through the same series of questions as those presented during routine day recollections.

Results

Research staff analyzed the results from the interviews by tabulating the frequencies of occurrence for each response category. Separate tabulations were made for speech and non-speech sounds and for the routine day and for incidents. These results are reported in the tables below.

Table 3 reports the number of hearing-critical job functions in a routine day (63) and the number of functions during responses to incidents (26), as described by the SMEs during the semi-structured interviews. Approximately equal numbers of hearing-critical job functions required the use of communication with speech or detection and recognition of non-speech sounds.

Table 3. Number and percent of hearing-critical job functions with speech communication and detection and recognition of non-speech sounds as functional hearing abilities.

Sound Type	Routine Day	Incident	Total	% of Total
Speech	32	10	42	47.2%
Non-Speech	31	16	47	52.8%
Total	63	26	89	100.0%

Locations

Table 4 shows the percentages of time functional hearing abilities were used in the performance of hearing-critical job functions at the most commonly reported locations in the facility. Separate entries are given for a routine day and during responses to incidents. During routine days, Correctional Officers used speech communication about a third of the time in the performance of hearing-critical job functions in housing areas. Correctional Officers also used speech communication to perform hearing-critical job functions in control booths and yards about 22% of the time. They used speech communication during responses to incidents in housing and yard areas 80% of the time.

Almost half of the time Correctional Officers used detection and recognition of non-speech sounds to perform hearing-critical job functions in housing areas. These functional hearing abilities were also used in the response to incidents in housing areas more than two-thirds of the time.

Table 4. Locations where speech and non-speech functional hearing abilities were used to perform hearing-critical job functions during a routine day and during responses to incidents.

	Speech		**Non-speech**	
Location	**Routine Day**	**Incidents**	**Routine Day**	**Incidents**
Housing	34.4%	40.0%	48.4%	68.8%
Yard	21.9%	40.0%	09.7%	12.5%
Control Booth	21.9%		12.9%	
Chow Hall	03.1%		19.4%	
Medical	03.1%	10.0%		06.2%
Visitation		10.0%		06.2%
Other	15.6%		09.7%	06.2%

Vocal effort, repetition, communication distance

Table 5 reports the level of vocal effort used to communicate with speech during a routine day and during responses to incidents. Normal vocal effort was used about 60% of the time during a routine day, while about 30% of the time raised or shouted vocal effort was used. This contrasts with the vocal effort used during responses to incidents, where 70% of the time Correctional Officers used raised or shouted vocal effort.

Table 6 displays information about the percent of time Correctional Officers could repeat speech communications. The results show that repetition was common, occurring 75-80% of the time both during a routine day and during responses to incidents. The data in Table 5 and

Table 6 reveal that elevated levels of vocal effort and repetition were commonly needed to achieve effective communication with speech while performing hearing-critical job functions.

Table 7 summarizes the percent of time speech communication took place at different distances. For both the routine day and during responses to incidents, the most commonly occurring communication distance was the shortest one, less than 5 feet. These data are consistent with the data in the preceding two tables, further indicating that short communication distances were also commonly used to achieve effective speech communication.

Table 5. Vocal effort used to communicate with speech during a routine day and during responses to incidents.

Effort	**Routine Day**	**Incidents**
Normal	59.4%	30.0%
Raised	18.8%	30.0%
Shout	12.5%	40.0%
Whisper	09.4%	00.0%

Table 6. Opportunity to repeat speech communications during a routine day and during responses to incidents.

Repetition	**Routine Day**	**Incidents**
Yes	75.0%	80.0%
No	25.0%	20.0%

Table 7. Distances over which speech communications occurred during a routine day and during responses to incidents.

Distance	Routine Day	Incidents
0-5 Feet	37.5%	50.0%
6-20 Feet	28.1%	30.0%
21+ Feet	34.4%	20.0%

Background noise levels

Table 8 reports the percentage of time background noise levels were judged to be either “quiet,” “medium,” or “loud” during a routine day and during responses to incidents. These levels are expected to be similar for both speech and non-speech functional hearing abilities. Noise levels were judged to be medium or loud over 90% of the time during the routine day, and approximately 50% of the time during responses to incidents for both types of functional hearing ability. The prevalence of medium and loud background noise levels helps to explain why elevated vocal effort, repetition, and short communication distances occur commonly during the performance of hearing-critical job functions. Quiet background noise levels were reported about 50% of the time during responses to incidents for both functional hearing abilities.

Given that incidents occur quite infrequently the data in Table 8 indicate that most of the time background noise levels are medium to loud when functional hearing abilities are used to perform hearing-critical job functions. The actual noise measurements and recordings made at locations where hearing-critical job functions are performed clearly support this observation.

Table 8. Judged background noise levels while speech and non-speech functional hearing abilities were used during a routine day and during responses to incidents.

	Speech		Non-speech	
Noise Level	**Routine Day**	**Incidents**	**Routine Day**	**Incidents**
Quiet	03.1%	50.0%	06.5%	43.8%
Medium	62.5%	30.0%	38.7%	37.5%
Loud	34.4%	20.0%	54.8%	18.8%

Accuracy and effort

Table 9 reports the accuracy of speech communications required while performing hearing-critical job functions during a routine day and during responses to incidents. As one would expect, highly accurate communication is necessary over 70% of the time during a routine day and 80% of the time during responses to incidents. Table 10 summarizes the amount of effort needed to achieve the required accuracy for both speech and non-speech functional hearing abilities.

During a routine day medium or high levels of effort are needed over 90% of the time for communication with speech and over 80% of the time for detection and recognition of non-speech sounds. High levels are needed over 60% of the time for both functional hearing abilities. This contrasts with the effort required during responses to incidents. Medium or high levels are needed about 50% of the time for both abilities, and high levels are needed about 30% of the time. These results were seen despite the fact that the required accuracy of speech communication during incidents is greater. Correctional Officers use high levels of vocal effort, repetition, and short communication distances during responses to incidents to achieve the required accuracy of speech communication, and in so doing reduce the effort necessary to achieve this level of accuracy.

Table 9. Required accuracy of speech communications during a routine day and during responses to incidents.

Accuracy	Routine Day	Incidents
High	71.9%	80.0%
Medium	25.0%	00.0%
Low	03.1%	20.0%

Table 10. Effort necessary to perform speech and non-speech functional hearing abilities during a routine day and during responses to incidents.

	Speech		Non-speech	
Effort	**Routine Day**	**Incidents**	**Routine Day**	**Incidents**
Low	06.2%	50.0%	16.1%	50.0%
Medium	31.2%	20.0%	22.6%	18.8%
High	62.5%	30.0%	61.3%	31.2%

Again, it is important to note that incidents occur only a small portion of the time. The remaining time during a Correctional Officer's routine day is characterized by the need to communicate with speech and to detect and recognize non-speech sounds during hearing-critical job functions when the noise level is high, requiring extra vocal effort, repetition, short communication distances, and extra overall effort.

Discussion

The hearing-critical job functions involving communication with speech performed during a typical routine day were mostly exchanges between Correctional Officers or between Correctional Officers and inmates. Many of these exchanges had a direct bearing on safety and security. Examples include the communications between Correctional Officers during inmate releases, inmate movements, and inmate counts. Correctional Officers also must continually monitor speech communication between inmates in housing areas, the chow hall and the yard. Speech communication is also essential for radio transmissions and telephone calls that are vital to coordinating and monitoring activities throughout the prison.

The importance of speech communication as a hearing-critical job function was even more evident from the incidents described by the SMEs. During incidents ongoing speech communication between Correctional Officers was often necessary in making a coordinated and appropriate response to the incident. Moreover, incidents were often detected by hearing speech communication by or between inmates. Examples include hearing an inmate call for help or hearing the verbal exchanges between inmates during a fight.

Finally, it should be noted that many of the hearing-critical job functions involving speech communication throughout the routine day and in response to incidents were reported to take place in noisy environments. Over 90% of these communications during the routine day occurred in medium or loud background noise environments. The SMEs reported that to achieve effective speech communication in these noise environments it was often necessary for Correctional Officers to use loud or even shouted vocal effort, to repeat their communications, and to use short communication distances.

Primary functional hearing ability

The fourth step in the research strategy was to determine the primary functional hearing ability to be examined throughout the remainder of the research.

Background and rationale

The results of the interviews with SMEs clearly pointed to the criticality of speech communication as a functional hearing ability. These findings have important implications for the hearing standard and for the screening measures used in the selection of applicants for the Correctional Officer job. This evidence allowed the direction of subsequent research steps to focus primarily on speech communication.

Methodology

To determine if speech communication was the primary functional hearing ability for the Correctional Officer job, research staff addressed several issues. The first was to determine whether there is adequate evidence of its importance. The second was to evaluate the significance of negative consequences of failed or ineffective speech communication during a routine day or while responding to incidents. The third was to justify the consideration of speech communication at the exclusion of detection, recognition, and localization of non-speech sounds. The fourth was to assess whether there is sufficient scientific knowledge showing how background noise affects the ability to communicate with speech for the purpose of hearing screening. Finally, the fifth was to identify well-established measures of speech communication that can be used for hearing screening. Each of these issues is addressed in turn below.

Results

Several aspects of the information gained from the SME interviews and from the analyses of the incident reports sharpened the focus of the research on speech communication. There was repeated evidence that speech communication between Correctional Officers and between Correctional Officers and inmates was a routine hearing-critical job function. Additionally, Correctional Officers must continually monitor the speech communication between inmates. These activities are vital to safety and the security of the facility. There was also repeated evidence that over 90% of the time speech communication occurred in moderate to high background noise levels. Further, there was evidence that Correctional Officers often found it necessary to use loud or shouted vocal effort, repetition, and short communication distances to achieve effective speech communication throughout a routine day. Further, effective speech communication was found to be of critical importance in maintaining the health and safety of inmates and Correctional Officers, for example:

- notifying the necessary personnel of a medical emergency,
- instructing inmates to cease certain actions, and
- warning another Correctional Officer of an imminent danger.

These findings led to the consideration of whether speech communication in noise was, in fact, one of the most important functional hearing abilities Correctional Officers used in the performance of hearing-critical job functions. If this were true, it would be important to obtain objective information about the noise environments in prisons where these functions take place. It would also be important to select appropriate measures of hearing impairment that are predictive of the ability to understand speech in noise. Such measures could be used to screen applicants for the Correctional Officer job. Based on these considerations, the research team defined speech communication as the primary functional hearing.

Importance of speech communication

Evidence of the importance of effective speech communication throughout a Correctional Officer’s typical routine day and during responses to incidents comes from interviews with SMEs that has been described above. The evidence strongly indicates that speech communication underlies many critically important job functions Correctional Officers perform.

Consequences of failed speech communication

During the interviews, the research team also asked the SMEs about possible negative consequences of failed or ineffective speech communication. The research team noted that the most serious consequences of failed speech communication could occur during responses to incidents. These include injury to Correctional Officers and/or inmates, inappropriate response to medical emergency, suicide, and escape. These consequences of failed speech communication can seriously jeopardize the health and safety of every person in the prison environment.

Consideration of non-speech sounds

The functional hearing abilities related to non-speech sounds are customarily defined as sound detection, sound recognition, and sound localization. However, for effective speech communication to occur, the speech sounds must also be detected, recognized, and, to some extent, localized. (When speech recognition is measured in noise with the speech and noise originating from different locations, the speech and noise are distinguished auditorily by their different locations.) Thus, if appropriate measures of speech communication are used for screening, evidence of adequate speech communication ability implies adequate non-speech functional hearing abilities.

Scientific knowledge about speech communication in noise

There is a substantial body of research literature that has examined the effects of noise on speech communication. (See Tufts et al., 2009, for a review.) Much of this literature has focused on how hearing impairment alters the ability to understand speech in noise. A standardized metric, the *Speech Intelligibility Index* (SII), has been used for many years to quantify the ability to understand speech in noise. Application of this metric to the prediction of speech understanding in everyday noise environments, such as those encountered in a Correctional Officer's routine day, has also been validated (Rhebergen & Versfeld, 2005; Rhebergen et al., 2006, 2008). This scientific knowledge, together with the SII standard, can be used for the purpose of hearing screening when speech communication in noisy environments is the primary functional hearing ability of interest.

Available measures of speech communication in noise

In recent years, a number of measures of speech communication in noise have been developed and published (e.g., Nilsson et al., 1994; Killion & Niquette, 2000; Bentler et al., 2000; Bilger et al., 1984; Cox et al., 1988; Kalikow et al., 1977). There is also a substantial body of both theoretical and applied research on the use of these measures and on the practical significance of the scores obtained with these measures. Recent studies have established a scientific link between this research and the research on speech communication in noise described above.

Discussion

Each of the issues is relevant to the focus on speech communication as the primary functional hearing ability required for the Correctional Officer job. This emphasis on speech communication concentrated the research efforts on the identification of times and locations within prisons where effective speech communication is necessary for hearing-critical job functions, and where achieving effective speech communication is difficult because of background noise levels. The SMEs identified these times and locations and assisted the research staff in the selection of the prisons for on-site visits.

The purpose of the on-site visits was to directly observe these hearing-critical job functions and to record the background noise during the performance of these functions. The strategy was to analyze the recordings so that the standardized metric used to predict the likelihood of effective speech understanding could be applied. Next, the effects of hearing impairment, as measured with tests of speech communication in noise, were introduced into the analyses. The results of these analyses were used to establish a validated hearing screening protocol and screening criteria based on published measures of speech communication in noise.

Selection of prisons for on-site observations and measurements

The fifth step in the research strategy was to select a representative sample of prisons for on-site observations and noise measurements.

Background and rationale

The research strategy called for on-site visits to a number of prisons for observation of hearing-critical job functions where speech communication was the primary functional hearing ability. The research team designed a sampling plan that identified a reasonable number of representative facilities throughout the state, since it was not practical to visit all 33 facilities throughout such a large state.

Methodology

Three different sampling criteria were used to form the sampling plan. The first criterion was the geographical region within the state. Three regions were defined: Northern, Central, and Southern. An attempt was made to sample approximately an equal number of facilities from each region.

The second, and perhaps most important, set of sampling criteria was the age of construction and architectural design of the facility. There are four identifiable designs throughout the states, and a number of facilities have more than one design. The design characteristics refer primarily to the housing areas within the facility where Correctional Officers spend a considerable amount of time and where many hearing-critical job functions involving speech communication take place, both throughout a routine day and during responses to incidents. Thus, appropriate sampling of architectural designs was essential.

Some of the oldest facilities utilize a *tiered housing design*, which is structured as a multi-level, multi-tiered cell block, with two to five floors. Cell doors usually consist of a horizontal and vertical bar grid, which does not attenuate sound.

Linear housing designs are single-story, long rectangular buildings with a corridor running down the center. Rooms housing inmates are on either side of the corridor. Cell doors are usually solid and attenuate sound.

Dormitory housing designs are large open facilities, often converted gymnasiums. Bunks of two or more levels are arranged in rows, leaving aisles for foot traffic. Showers, toilets, and day room areas adjoin the bunks, as well as a control station to Correctional Officers. Entrance to the facility is through a single solid door.

180 degree and 270 degree housing designs are so named because of the Correctional Officer’s view from the central elevated control booth. Two floors of cells are arrayed around the control booth, with a dayroom separating the control booth from the cells on the lower level. The control booth is typically enclosed by large windows with thick glass, although some of the windows can be opened. Sound from the housing area is attenuated both by distance and by the glass. Cell doors are solid. Much of the speech communication between the Correctional Officer in the control booth and individuals on the floor or in the cells requires loud or shouted vocal effort.

Facilities with each type of architectural construction were included in the sample. Appendix E provides additional detail about each type of housing design.

The third sampling criterion was the security level (threat level) of inmates housed in the facilities. The security level is defined by the type of inmate housing, the type of perimeter security, and the level of staffing. There are four security levels, and facilities throughout the state include multiple security levels. Appropriate sampling of the type of housing and the level of staffing is of primary importance for the hearing standard. The lowest security levels (I and II) use open dormitory housing, and the highest security levels (III and IV) use individual cells. Both types of housing were included in the seven prisons that were sampled.

The fourth sampling criterion was the gender of inmates housed in the facility. Because a disproportionate number of state prisons are for men, one women's prison was included in the sample.

Results

The research team selected seven facilities for the on-site measurements. The geographical region, facility location and architectural design, and security levels for each of the seven facilities are given in Table 11. A total of 3 Northern, 2 Central and 2 Southern facilities were chosen. These facilities represent the range of construction design used for housing throughout the state prison system. All of the sampled facilities had dormitory housing, which is not shown in the table. Most of the facilities had all four levels of security, with the exception of Folsom State Prison which does not house Level IV inmates because of its age and tiered construction. Recordings were made at these facilities between November 2009 and February 2010. For a detailed description of these seven prisons, please see Appendix F.

Table 11. Characteristics of the seven prisons selected for on-site visits.

Region	Location	Name	Design	Security
North	Mule Creek	Mule Creek State Prison	270	I-IV
North	Folsom	Folsom State Prison	Tiered	I-III
North	Folsom	California State Prison	270	I-IV
Central	Chowchilla	Valley State Prison for Women	270, linear	I-IV
Central	Salinas	Salinas Valley State Prison	270, linear	I-IV
South	Kern	North Kern Valley State Prison	180	I-IV
South	Tehachapi	California Correctional Institute	Unique	I-IV

Discussion

The facility sampling plan produced approximately equal numbers of prisons from each geographical region. All architectural housing designs were also included. Only one tiered design (Folsom State Prison) was included because there so few old prisons in the state built with this design. California Correctional Institute was designated as having a “unique” architectural housing design because the facility included all designs except tiered. Thus, the sample included a total of one tiered design, two linear designs, seven dormitory designs, and five 180 or 270 designs. The 180 and 270 designs were combined for sampling purposes because of the similarity in their architectures and, consequently, the similarity in background noise environments where Correctional Officers perform hearing-critical job functions that require effective speech communication.

Selection of locations and times for on-site observations and measurements

The sixth step in the research strategy was to selection locations and times within each prison where hearing-critical job functions take place.

Background and rationale

For each of the facilities sampled in the previous step research staff identified the locations and times where Correctional Officers perform hearing-critical job functions involving speech communication. Staff used this information to plan on-site visits to observe and document the performance of these functions and to record the background noise. The recordings were subsequently analyzed to quantify the likelihood of effective speech communication during Correctional Officers’ performance of these functions in these noise environments. These analyses were also used to determine the effects of hearing impairment on the ability to perform these functions.

Research staff made high quality digital audio recordings of background noise environments in a sample of prisons throughout the State of California. Research staff chose the locations and times of the recordings within each facility based on analysis of the incident reports, the SME panel interviews, and the SME interviews at the each of the sampled facilities. This selection best captured the locations where, and times when, hearing-critical job functions are performed. Research staff processed and analyzed these recordings to obtain distributions of ESII values for each location. Using these distributions, the likelihood of effective communication was calculated for each location, as well as the overall likelihood of effective communication throughout the day. The likelihood values provided validation for setting hearing screening criteria in terms of the HINT Composite SRT. A detailed description of the methodology and results for this process is given in this section of the report.

Methodology

Research staff employed a two-step process to identify the locations and times at each facility where hearing-critical jobs functions involving speech communication are performed. The first step involved the selection of times and locations based on the information from the semi-structured interviews with SMEs. Staff used this information to form a prioritized list of the most important times and locations to be visited at each facility.

Top priority (A) was assigned to locations where Correctional Officers spend a substantial amount of time and where Correctional Officers perform a number of hearing-critical job functions involving speech communication. These locations were visited first at each facility. Secondary priority (B) was assigned to locations where Correctional Officers spend less time and where fewer hearing-critical job functions take place.

The information in the list was not facility-specific, as it represented the information obtained and compiled from Correctional Officers working in prisons across the entire state. Thus, as a second step, the research team conducted interviews with Correctional Officers who worked at each facility at the beginning of each on-site visit. Research staff reviewed the prioritized list with the Correctional Officers at each prison and asked how the list could best be adapted to the specific locations and schedules in place at their facility. After any needed adjustments were made to the list, research staff planned a detailed schedule for visiting each location at the targeted prison.

Results

Table 12 shows the prioritized list of locations and times for on-site visits identified from the interviews with SMEs. There were seven locations and times with “A” priority and six locations and times with “B” priority.

Table 12. Prioritized list of locations and times used for scheduling on-site recordings

Priority	Location	Time
A	Control booth	Morning, late afternoon
A	Movement areas in housing units	All
A	Dorm and cell housing	All
A	Dining hall	When in use
A	Yard	Mid-morning, early afternoon
A	Movement areas other than housing	According to schedule
A	Receiving & Releasing	According to schedule
B	Dayroom	When in use
B	Kitchen	Early morning, mid afternoon
B	Gym	When in use
B	Medical areas	Mornings
B	Central control	All
B	Visitation area	According to schedule

Discussion

The prioritized list of locations and times for on-site recordings of background noise environments provided an efficient way to ensure that the research team observed the most important hearing-critical job functions involving speech communication. The pre-observation interviews identified specific spots at each location that were noisiest or where the most important speech communication activities occurred. Time schedules were also set to make the most efficient use of time available at the facility.

The on-site visits to each location at each facility allowed research staff to obtain observations and recordings that objectively documented the functional hearing requirements for Correctional Officers. The following steps describe how the recordings were made, analyzed, and interpreted for this purpose.

Background noise recordings and measurements

The seventh step in the research strategy was to record and measure background noise environments where hearing-critical job functions occur.

Background and rationale

The intended use of the background noise recordings was to provide quantitative information about the noise environments where Correctional Officers must achieve effective speech communication to perform hearing-critical job functions throughout the routine day and during responses to incidents. By making calibrated recordings of these noise environments, it was possible to use a standardized metric, the Speech Intelligibility Index (American National Standards Institute, 2007), to predict the likelihood that otologically normal Correctional Officers can achieve this level of performance. Published methods for calculating the SII and for making these predictions are available for this purpose. These methods have recently been extended to apply to everyday noise environments, such as those encountered by Correctional Officers in a routine day.

Use of the extended SII methods requires that the moment-to-moment variations in noise level and frequency be known. With calibrated recordings of the noise environments at appropriate times and locations, well-defined methods of analysis (American National Standards Institute, 2007) can be used to process the recordings, providing the necessary details about the level and frequency of the noise. These details, in turn, can be used to determine the likelihood of effective speech communication in each noise environment. The same methods can also be used subsequently to determine how hearing impairment affects performance. The detailed methodology for making these recordings is summarized in Appendix G. A summary of the key aspects of the methodology is given below.

Methodology

All recordings were made using a hand-held digital audio recorder, the Edirol R-09HR manufactured by Roland. Recordings were stored on a digital memory card and later transferred to a personal computer for data processing and analysis. Procedures for calibration of the recordings are given in Appendix H.

Results

The research team made a total of 87 recordings at the specified locations from the 7 facilities. Four of these recordings were not useable, leaving a total of 83 recordings for analysis. A detailed summary of each recording is given in Appendix I.

Table 13 presents a brief summary of the recordings. The recordings are organized according to location within the facilities. For each location, e.g., “control booth,” the number of recordings made at each facility and the total number of recordings is given. Note that none of the locations included recordings from all 7 facilities. Certain locations were not available at some prisons; e.g., not all prisons have laundries. Other locations were not available due to scheduling or security considerations. Thus, the number of recordings for each location varied widely. Research staff subsequently made corrections for this source of variability before the final analyses were performed.

The fourth column in Table 13 contains the total duration in seconds of the recordings for each location. The total duration of all recordings was over 420 minutes, or 7 hours. Perhaps the most important pieces of information to note about the recordings are the background noise levels reported in the last two columns of the table. Noise levels are measured in dB (A), the standard units for describing noise, and represent the average noise level over the entire duration of an individual recording. The column labeled “Max” reports the highest average level across all noise recordings for the specified location, and the column labeled “Min” reports the lowest average level. Long-term exposure to average levels above 85 dB (A) place one at risk for noise-induced hearing loss. The highest maximum value, 89.7 dB (A) in kitchen locations, is shaded, as is the lowest minimum value, 62.0 dB (A) in laundry locations.

Discussion

The noise recordings provide a representative sample of the noise environments where Correctional Officers perform hearing-critical job functions throughout the routine day and during responses to incidents. The sample includes data from a representative set of prisons throughout the state, including the full range of architectural designs and security levels, as well as both inmate genders.

The sample includes only recordings made at locations and times where important hearing-critical job functions involving speech communication occur. Thus, subsequent analyses based on the SII standard and the published methods that extend these analyses to everyday noise environments will allow an accurate characterization of the likelihood that otologically normal Correctional Officers can achieve effective speech communication when performing hearing-critical job functions at these locations.

Table 13. Summary of on-site noise recordings.

Location	Facilities	Recordings	Duration	Noise level	
				Max	Min
Control booth	5	8	53.5	78.7	62.1
Chow hall	6	8	36.6	83.0	75.4
270-180 housing	4	7	23.5	79.3	69.4
Dorm housing	3	7	29.1	84.1	72.4
Linear housing	1	1	3.5	70.1	
Tiered housing	1	4	17.7	81.7	73.4
Kitchen	5	10	48.3	89.7	73.8
Laundry	3	4	15.7	85.6	62.0
Medical	5	8	46.9	82.4	65.0
R&R	3	7	58.5	87.5	68.8
Vocational	2	7	32.1	88.8	75.8
Visitation	2	5	23.4	79.5	66.3
Yard	4	7	35.8	84.4	71.9
TOTAL		83	424.5		

Perhaps the most striking evidence to emerge at this step is the information about the background noise levels where Correctional Officers perform hearing-critical job functions. Considering first the maximum average noise levels from each location, all of these maxima except one exceed 78 dB (A), which would be considered "exceedingly loud." These on-site measurements are entirely consistent with SME reports during the interviews that background noise levels are moderate to loud over 90% of the time throughout a routine day. In fact, measured maximum noise levels are more accurately categorized as "loud" to "exceedingly loud." Likewise, measured minimum noise levels are greater than 70 dB (A) for half the locations, and between 62 dB (A) and 70 dB (A) for the other half. Measured noise levels over 70 dB (A) would also be considered "loud," while the lower minimum noise levels would be considered "moderate."

These documented background noise environments provide additional support for the research strategy focusing on speech communication in noise as the primary functional hearing ability for Correctional Officers. These findings are also consistent with the evidence from SME interviews that Correctional Officers must often use loud or shouted levels of vocal effort, repetition, and very short communication distances to achieve effective speech communication. The next step of the research consisted of analyses that provided quantitative information about the impact of these high background noise environments on the performance of hearing-critical job functions.

Analysis of noise recordings

The eighth step in the research strategy was to perform standardized analyses of the noise recordings.

Background and rationale

The Speech Intelligibility Index (SII) is a standardized metric for predicting speech intelligibility, or speech understanding, in stationary non-fluctuating noise (American National Standards Institute, 2007). The SII has recently been extended to predict speech intelligibility in fluctuating noise as well, such as found in everyday noise environments (Rhebergen & Versfeld, 2005; Rhebergen et al., 2006, 2008). The Extended SII, or ESII, can be used to predict speech intelligibility and the likelihood of effective speech communication for otologically normal Correctional Officers in each of the noise environments where they perform hearing-critical job functions throughout a routine day and during responses to incidents.

The SII and ESII are based on the principal that the level of the information in speech in relation to the level of the noise determines intelligibility and the likelihood of effective speech communication. The importance of information in speech for intelligibility and effective communication is not the same at all frequencies. For example, speech information below 2000 Hz is more important than speech information above 2000 Hz. To calculate the SII and ESII it is necessary to filter the noise into narrow frequency regions and to determine the level of the noise in each region. The level of speech in each frequency region is stated in the standard (American National Standards Institute, 2007). The level of the speech in relation to the noise in each frequency region, together with the importance of the speech information in each region, allow the SII and ESII to be calculated.

The speech levels used to calculate the SII and ESII can vary depending on the vocal effort used to produce the speech. The standard allows a “normal,” “raised,” “loud,” or “shouted” level of vocal effort to be specified. Raised, loud, and shouted levels of vocal effort are most appropriate for use in the analyses because SMEs reported and research staff observed on-site almost constant use of these levels of vocal effort by Correctional Officers.

The standard also allows communication distance to be specified. Again, the SME reports as well as the observations during on-site recordings indicated that relatively short communication distances were commonly used because of high background noise levels.

In fluctuating background noise there are times when the noise level drops, making speech communication easier and more effective. There also are times when the noise level increases, making speech communication more difficult and less effective. Thus, it is appropriate to consider the likelihood of effective speech communication in fluctuating background noise. The ESII provides an effective means of quantitatively characterizing this likelihood for otologically normal individuals. The ESII for a fluctuating noise environment is determined by first calculating the SII over and over on brief “snapshots” of the noise, approximately 100 per second, and then averaging these values over the entire duration of the noise (Rhebergen &

Versfeld, 2005; Rhebergen et al., 2006, 2008). This method can be readily adapted to determine the ESII for a segment of the noise, rather than the entire duration of the noise. The standard states that “good” speech communication can occur when the SII exceeds 0.45 This also applies to the ESII; however, when binaural hearing and the opportunity to repeat communications are considered, this value decreases to 0.30. Appendix J provides the detailed rationale for using 0.30 as the criterion value.

Most brief two-way communications between individuals take place over a few seconds, e.g., 4 seconds. Thus, by calculating the ESII for a 4 second segment of the noise it is possible to determine whether effective speech communication can occur during that segment. ESII values over 0.30 indicate that it can, and values under 0.30 indicate that it cannot. Finally, if an entire on-site noise recording is divided into 4 second segments and the ESII for each segment is calculated, the percent of segments with ESII values over 0.30 corresponds to the percent of time effective speech communication can occur in the fluctuating noise environment. This percentage is defined as the likelihood of effective speech communication in that noise environment for an otologically normal individual.

Research staff used these analyses to determine the likelihood of effective speech communication for Correctional Officers with normal hearing at the times and locations where Correctional Officers perform the most important hearing-critical job functions involving speech communication. Research staff also repeated these analyses to determine the type and degree of hearing impairment that reduces the likelihood of effective speech communication to a level where safe and effective job performance could become an issue. This approach provides an explicit and objective connection between the measures of hearing impairment to use for screening applicants for the job and the hearing-critical job functions that Correctional Officers must perform during a routine day and when responding to incidents.

Methodology

Research staff manually edited the on-site recordings from each location at each facility to remove spoken comments by the individuals making the recordings and comments by Correctional Officers and other prison staff, leaving only the background noise for subsequent analysis. The remaining background noise often consisted of the voices of staff and inmates in addition to the sounds of equipment and other sounds typically present in those environments.

The edited recordings were processed according to the procedures specified in the standard (American National Standards Institute, 2007). The noise was filtered into 1/3 octave bands with center frequencies ranging from 160 Hz to 8000 Hz. Calibrations were applied to each noise band, and the SII was calculated ever 9.2 milliseconds from noise “snapshots” and averaged over 4 second intervals to produce ESII values. These calculations were repeated for several levels of vocal effort and several communication distances. Cumulative frequency distributions of the resulting ESII values were formed. These ESII data sets were used to determine the likelihood of effective speech communication for various combinations of vocal effort and communication distance at each location and time at each facility where Correctional Officers perform hearing-critical job functions. A detailed description of this methodology is given in Appendix K.

Results

Research staff processed each of the 83 recordings according to the procedure described above to produce an ESII data set for each recording. The spectral characteristics of each recorded noise environment were summarized by calculating mean levels for each frequency band, the level below which 10% of the band levels fell (L10), and the level below which 90% of the band levels fell (L90). Of primary interest were the cumulative distributions of ESII values from each location. Analysis of these distributions quickly revealed that the ESII values for communication distances of 5 and 10 meters were uniformly low, often 0.00. Consequently, these two communication distances were not included in the subsequent analyses.

Discussion

The 83 ESII data sets represent measurements and analyses from 13 different locations at 7 different prisons. The size of each data set, as well as the number of data sets from each location and each facility, varied in an unsystematic manner, complicating interpretation of the analyses. These considerations made it necessary to pool and weight the ESII data sets to control these unsystematic variations. The next step in the research strategy addressed these considerations.

Likelihood estimates of effective speech communication

The ninth step in the research strategy was to estimate the likelihood of effective speech communication in prison noise environments.

Background and rationale

Research staff used the semi-structured interviews with SMEs and the analyses of the incident reports to define locations and times within prisons where important hearing-critical job functions that require communication with speech occur throughout a routine day and during responses to incidents. This information, in turn, was used to plan on-site recordings and observations at appropriate locations and times. Thus, pooling and weighting of ESII data sets provided representative estimates of the likelihood of effective speech communication for each location. Research staff pooled data sets from the same locations at different facilities, e.g., data sets from on-site recordings in control booths, to give equal weight to data from each facility. These pooled data sets for different locations were weighted according to the frequency and importance of hearing-critical job functions involving speech communication that are performed at each location. Finally, research staff pooled the weighted data sets for each location to produce an overall estimate of the likelihood of effective speech communication throughout a Correctional Officer's routine day and during responses to incidents.

Methodology

Research staff first grouped the ESII data sets from multiple locations and multiple facilities according to location. A total of 9 locations were identified as the most important locations for hearing-critical job functions: control booth, chow hall, housing, kitchen, laundry and vocational, medical, receiving and releasing, visitation, and yard. Housing was further divided into 4 types based on construction design: 270/180, dorm, tiered, and linear. Research staff applied several constraints in the pooling and weighting of data sets to make the sets most representative.

The first constraint was that no more than 5 data sets from different facilities were used in the analysis for any location. In some cases more than 5 sets were available, but their use would have meant that unequal numbers of data sets were contributed by some facilities. When more than 5 sets were available, research staff selected the 5 from different facilities that had the widest range of overall noise levels.

The second constraint occurred because of the size of the data sets. Using the smallest selected data sets as a guide, research staff sampled 2 minutes of ESII data from each data set. Thus, average ESII values for 30 4-second intervals were drawn from each data set. These 30 intervals were distributed uniformly over the entire duration of the data set. This controlled the imbalance in the representativeness of data sets due to the size of the contributing data sets and to the number of facilities represented.

The third constraint arose from the need to produce a single overall estimate of the likelihood of effective speech communication throughout a routine day. The amount of time in a day that a Correctional Officer spends at locations is not equal. Thus, the contributions of each location to the overall estimate were weighted according to the amount of time and importance of hearing-critical job functions associated with each location.

Results

Table 14 summarizes the results of the pooling and weighting process. The weights in column 5 are based on the frequency and importance of hearing-critical job functions involving speech communication that take place at each location throughout the day. Control booths, for example, were weighted 0.16, and kitchen areas received a weight of 0.09. Housing received a weight of 0.40, the largest weight allocation for any of the locations, reflecting the importance of hearing-critical job functions performed in and around the housing area. Because there are different types of prison housing designs, the weight of 0.40 was split among the four different housing designs proportional to their prevalence throughout the entire state system. The most common designs are 270/180 and dorm housing, whereas very few facilities have tiered and linear housing.

The final columns in Table 14 provide the likelihood of effective speech communication at a close distance of 0.5 meters under different levels of vocal effort. The levels of vocal effort represented are normal voice, raised voice, loud voice, and shouted voice.

To illustrate how to read the information in Table 14, consider control booths. The pooled ESII data for the control booth location was from 5 different recordings, and each recording came from a different facility. The likelihood of effective speech communication at control booths using normal vocal effort at a distance of 0.5 meters is 0.69. This likelihood increases to 1.0 for greater levels of vocal effort. These likelihood values are weighted by 0.16 when combined with the other weighted likelihood values to produce the overall estimate of the likelihood of effective speech communication throughout an entire day. In the example shown in the table, the overall likelihood estimate is 0.42 when normal vocal effort is used. This value increases to higher likelihoods as vocal effort is increased, and reaches 1.00 with shouted vocal effort.

Table 14. Locations selected to comprise the routine day of a Correctional Officer for communication at a distance of 0.5 meters

	Location	Number of measures	Number of facilities	Weight		Vocal Effort at 0.5 meters N	R	L	S
1	Control booth	5	5	0.16		0.69	1.00	1.00	1.00
2	Chow hall	5	5	0.05		0.00	0.42	0.95	1.00
3	Housing: 270/180	4	4	0.18		0.81	0.98	1.00	1.00
4	Housing: Dorm	5	3	0.18		0.01	0.38	0.93	1.00
5	Housing: Tiered	3	1	0.03		0.00	0.40	0.99	1.00
6	Housing: Linear	1	1	0.01		0.80	1.00	1.00	1.00
7	Kitchen	5	5	0.09		0.00	0.19	0.45	0.99
8	Laundry/Vocational	5	3	0.01		0.00	0.11	0.47	0.93
9	Medical	5	5	0.06		0.73	0.89	1.00	1.00
10	Receiving & Releasing	5	3	0.06		0.75	0.99	1.00	1.00
11	Visitation	5	2	0.01		0.28	0.79	0.99	0.99
12	Yard	5	5	0.16		0.37	0.89	1.00	1.00
	OVERALL	53		1.00		0.42	0.73	0.93	1.00

Note. For Vocal Effort: N = Normal; R = Raised; L = Loud; S = Shouted.

Discussion

The results of pooling and weighting the ESII data sets to estimate the likelihood of effective speech communication throughout a Correctional Officer's routine day provide several objective insights into the hearing requirements for the job. The data in Table 14, which apply only to otologically normal Correctional Officers, reveal that even these individuals do not experience a high likelihood of effective speech communication at all times. For example, speech produced with normal vocal effort is likely to result in effective communication less than half the time throughout the day. This likelihood increases to 0.73 with raised vocal effort, and reaches 0.93-1.00 with loud or shouted speech. In the noisiest locations, e.g., kitchen and laundry/vocational areas, only shouted speech at short distances results in effective speech communication. In the locations with the highest weights, e.g., control booth, housing, and yard areas, raised or loud vocal effort usually can result in effective speech communication.

Effective speech communication is challenging for all Correctional Officers at many times and locations throughout the routine day. However, it may be even more challenging more often for hearing impaired individuals. The next step in the research strategy was to examine how hearing impairment, as measured in two different ways, affects the likelihood of effective speech communication in the challenging noise environments where Correctional Officers must perform hearing-critical job functions that include communication with speech.

Impact of hearing impairment on likelihood estimates

The tenth step in the research strategy was to determine the impact of hearing impairment on the likelihood of effective speech communication.

Background and rationale

The ESII calculations described above apply to otologically normal individuals (American National Standards Institute, 2007). These calculations show that even with normal hearing, the likelihood of effective speech communication in some locations and on average throughout a routine day is not always high. Thus, the question becomes how hearing impairment affects the likelihood of effective speech communication.

Hearing impairment can be quantified in two different ways to address this question. One aspect of hearing impairment is reduced audibility, as quantified by elevation of pure-tone thresholds above normal. The other aspect of hearing impairment is the need for more favorable signal/noise ratios (SNRs) to understand speech when both the speech and noise are audible, as quantified by elevation of the speech reception threshold (SRT) in noise above normal. Both aspects of hearing impairment can be systematically introduced into the ESII calculations either separately or together. The standard upon which the ESII is based (American National Standards Institute S3.5-1997, 2007) specifies how elevated pure-tone thresholds are applied in the calculations. Thus, the effects of elevated thresholds on the likelihood of effective speech communication can be determined directly by recalculating the distribution of ESII values for each pattern of elevated thresholds to determine how the likelihood of effective speech communication is decreased.

The effects of elevated SRTs are determined by other means. An individual whose SRT is elevated above normal requires a larger ESII value for effective speech communication (Houtgast & Festen, 2008). For example, an otologically normal individual requires an ESII of 0.30 or better for effective speech communication. However, an individual whose SRT is 1 dB higher (poorer) than the average requires an ESII of 0.33 for effective speech communication. In other words, the ESII required for effective speech communication increases by 0.03 for every 1 dB increase in SRT. Thus, the effects of elevated SRTs on the likelihood of effective speech communication are determined from the distribution of elevated ESII values corresponding to elevated SRTs of different magnitudes. Using this approach, research staff calculated the effects of hearing loss on the likelihood of effective speech communication throughout a Correctional Officer's routine day for different degrees and configurations of pure-tone hearing loss and for different magnitudes of SRT elevation.

Methodology

Research staff selected five different configurations of pure-tone hearing loss likely to be seen among applicants for Correctional Officer jobs, in addition to the configuration for an individual with normal pure-tone thresholds, i.e., a 0 dB flat hearing loss at all frequencies (0 F). These configurations are summarized below. Note that pure-tone threshold elevation above normal is measured in dB Hearing Level, or dB HL. For example, a threshold of 50 dB HL is 50 dB higher (poorer) than that of the average otologically normal individual. The abbreviations for each configuration used in the tables and charts are also given below.

- Borderline normal audiogram: 25 dB flat loss at all frequencies for both ears (25 F).
- Moderate conductive hearing loss: 50 dB HL flat loss at all frequencies for both ears (50 F).
- Moderate sensorineural hearing loss: thresholds increase from 20-50 dB HL in both ears as frequency increases from 160 Hz to 8000 Hz (50 S).
- Severe sensorineural hearing loss: thresholds increase from 20-70 dB HL in both ears as frequency increases from 160 Hz to 8000 Hz (70 S).
- Noise-induced hearing loss: 20 dB HL thresholds up to 2000 Hz, dropping to 60 dB HL at 4000 Hz, and rising to 30 dB HL at 8000 Hz, commonly known as a "noise notch" (60 NN).

Research staff calculated ESII for each hearing loss configuration using four levels of vocal effort (normal, raised, loud, shouted) and two communication distances (0.5 meters and 1.0 meters). These calculations were used to determine the likelihood of effective speech communication for each set of parameters and each hearing loss configuration, given normal SRTs. Research staff did not include the two greater communication distances because even individuals with normal pure-tone thresholds and normal SRTs had very low likelihoods of effective speech communication at these distances.

Research staff used the previous ESII calculations for otologically normal individuals to determine how the likelihood of effective speech communication decreases as SRTs increase, thus increasing the magnitude of the ESII required for effective communication. Together these analyses allow the effects to be calculated for both types of hearing loss on the likelihood of effective speech communication throughout a routine day for Correctional Officers.

Results

The results of these analyses are reported in four chart-table sets. The first two sets examine the effects of hearing loss configuration on the likelihood of effective speech communication using normal, raised, loud, and shouted vocal effort at a distance of 0.5 meters. For ease of interpretation, the likelihood values for each hearing loss configuration have been expressed as the proportional reduction in the likelihood of effective speech communication in relation to the likelihood of effective speech communication for an individual with normal pure-tone thresholds (0 F). These values are referred to as "proportional likelihoods" in the charts below.

Effects of hearing loss configuration: 0.5 meter communication distance

The table preceding each chart contains the actual minimum and maximum likelihood values for each hearing loss configuration over a 5 dB range of SRT elevations. For example, in Table 15 the likelihood of effective speech communication with normal vocal effort at 0.5 meters ranged from 0.37 to 0.18 for individuals with a 25 dB flat loss (25 F), depending on the elevation of the

SRT. The maximum likelihood value (0.37) is associated with individuals with normal SRTs (0 dB threshold elevation), and the minimum likelihood value (0.18) is associated with individuals whose SRTs are elevated 5 dB above normal.

Table 15. Absolute likelihoods of effective speech communication at 0.5 meters for different vocal efforts and hearing loss configurations.

Pure-tone hearing	Normal		Raised		Loud		Shouted	
	Max	Min	Max	Min	Max	Min	Max	Min
0 F	0.42	0.19	0.73	0.53	0.93	0.79	1.00	0.96
25 F	0.37	0.18	0.72	0.51	0.93	0.78	1.00	0.96
50 F	0.24	0.00	0.72	0.45	0.93	0.78	1.00	0.95
50 S	0.40	0.16	0.72	0.50	0.93	0.78	1.00	0.95
70 S	0.16	0.00	0.66	0.28	0.91	0.72	1.00	0.95
60 NN	0.38	0.15	0.72	0.49	0.93	0.78	1.00	0.96

For each amount of SRT elevation, ranging from 0-5 dB above normal and each level of vocal effort, the effects of a hearing loss configuration were expressed as the proportional reduction in the likelihood of effective speech communication in relation to the likelihood for an individual with normal pure-tone thresholds. These proportional reductions were then averaged across the range of SRT elevation to produce a single proportional likelihood that quantifies the effects of the hearing loss configuration on the relative likelihood of effective speech communication. Table 15 displays the pattern of proportional likelihoods for each level of vocal effort and each hearing loss configuration.

Using normal vocal effort as an example, individuals with a 25 dB flat loss (25 F) have a likelihood of effective speech communication equal to 0.91 of the likelihood for individuals with 0 dB flat loss (0 F). Likewise, individuals with a 50 dB flat loss have a likelihood of only 0.18 of that of individuals with a 0 dB flat loss.

Referring again to Table 15 above, note that the likelihood of effective speech communication for individuals with normal pure-tone thresholds (0 F) ranges from 0.19-0.42, so reductions in the proportion likelihood mean not only that hearing loss configurations reduce relative likelihoods, as compared with individuals who have normal pure-tone thresholds, but also that the absolute likelihood of effective speech communication is extremely low. Note also that the picture changes dramatically as vocal effort is increased. Raised, loud, and shouted vocal efforts appear to easily overcome the effects of pure-tone hearing loss, with proportional likelihoods greater than 0.90 except for the most severe hearing loss configuration (70 S).

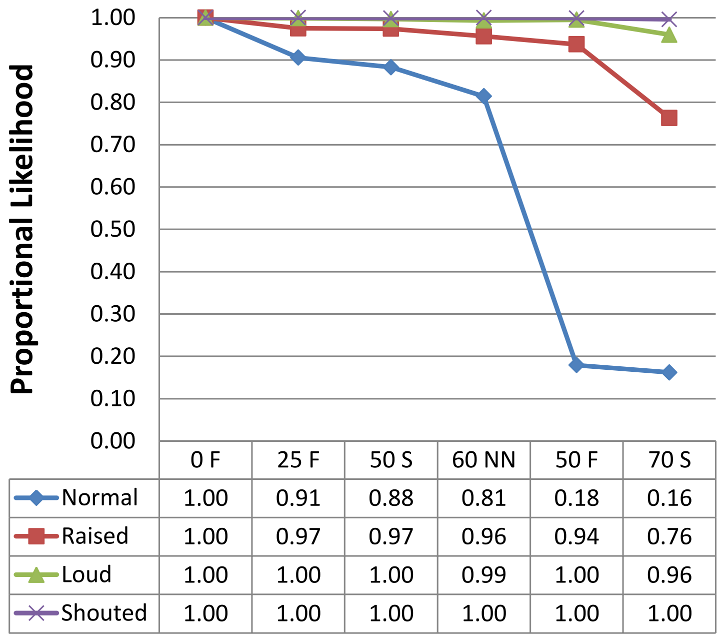


Figure 2. Proportional likelihoods of effective speech communication at 0.5 meters for different vocal efforts and hearing loss configurations.

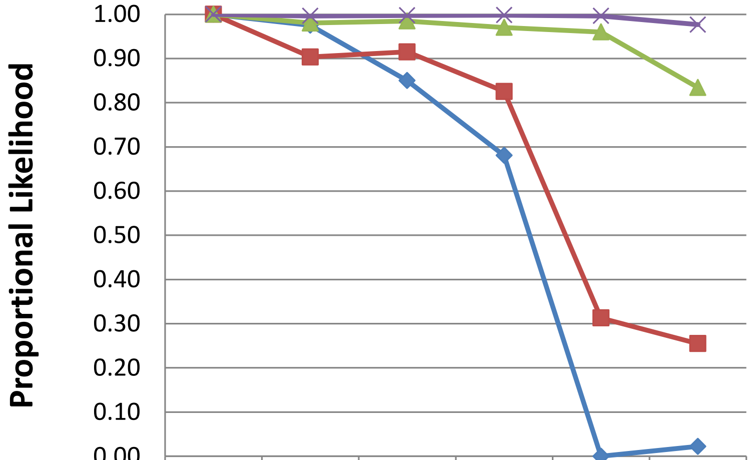
Effects of hearing loss configuration: 1.0 meter communication distance

Table 16 displays the same information relating hearing loss configuration to the likelihood of effective speech communication for communication distances of 1 meter. Note that in general the absolute likelihood values are substantially lower than those seen for communication distances of 0.5 meters, except for shouted speech. This suggests that the effects of the greater distance on the likelihood of effective speech communication can be overcome by shouting in many instances.

Table 16. Absolute likelihoods of effective speech communication at 1.0 meter for different vocal efforts and hearing loss configurations.

Pure-tone hearing	Normal		Raised		Loud		Shouted	
	Max	Min	Max	Min	Max	Min	Max	Min
0 F	0.16	0.05	0.48	0.23	0.77	0.57	0.95	0.82
25 F	0.16	0.05	0.45	0.21	0.77	0.55	0.95	0.82
50 F	0.00	0.00	0.35	0.01	0.76	0.52	0.95	0.82
50 S	0.13	0.01	0.47	0.19	0.77	0.55	0.95	0.82
70 S	0.00	0.00	0.24	0.01	0.72	0.37	0.95	0.78
60 NN	0.14	0.03	0.44	0.17	0.76	0.54	0.95	0.82

Table 16 showing the effects of hearing loss configuration and vocal effort on the proportional likelihood of effective speech communication at a distance of 1 meter exhibits a similar pattern to the chart for communication distances of 0.5 meters. However, at this distance both normal and raised vocal efforts are relatively ineffective for the 60 NN, 50 F, and 70 S hearing loss configurations. Again, loud and shouted vocal efforts are effective in overcoming the effects of pure-tone hearing loss, with proportional likelihoods greater than 0.90 except for the 70 S hearing loss configuration.



	0 F	25 F	50 S	60 NN	50 F	70 S
Normal	1.00	0.98	0.85	0.68	0.00	0.02
Raised	1.00	0.90	0.92	0.83	0.31	0.25
Loud	1.00	0.98	0.98	0.97	0.96	0.83
Shouted	1.00	1.00	1.00	1.00	1.00	0.98

Figure 3. Proportional likelihoods of effective speech communication at 1.0 meters for different vocal efforts and hearing loss configurations.

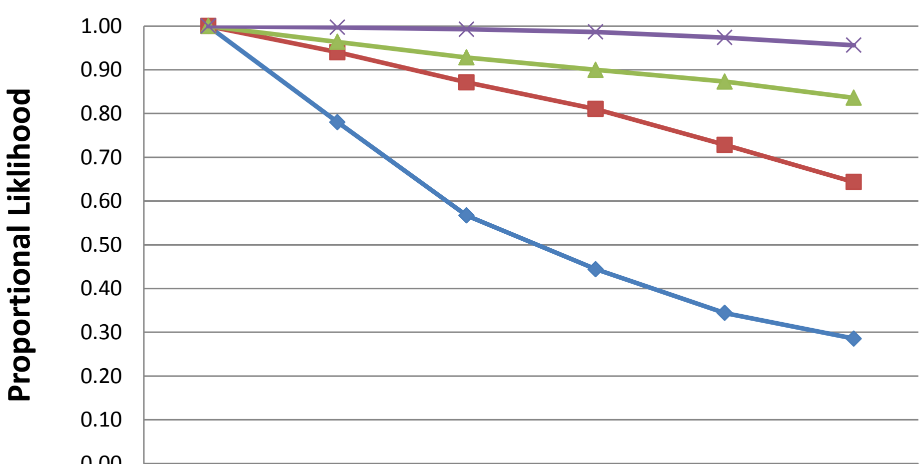
Effects of SRT elevation: 0.5 meter communication distance

The remaining two chart-table sets examine the effects of SRT elevation on the likelihood of effective speech communication over a distance of 0.5 meters using normal, raised, loud, and shouted vocal effort. For these analyses, the maximum and minimum likelihoods shown in Table 17 below have been calculated for each SRT elevation over the range of hearing losses. The maximum likelihood is associated with normal pure-tone thresholds (0 F) and the minimum likelihood is associated with the most severe hearing loss configuration (70 S). Note again the likelihoods are not exceedingly high, except for loud and shouted levels of vocal effort.

Table 17. Absolute likelihoods of effective speech communication at 0.5 meter for different vocal efforts and SRT elevations.

SRT elevation	Normal		Raised		Loud		Shouted	
	Max	Min	Max	Min	Max	Min	Max	Min
0 dB	0.42	0.16	0.73	0.66	0.93	0.91	1.00	1.00
1 dB	0.37	0.11	0.70	0.60	0.89	0.88	1.00	0.99
2 dB	0.32	0.03	0.65	0.55	0.86	0.84	0.99	0.99
3 dB	0.28	0.01	0.61	0.48	0.84	0.81	0.99	0.98
4 dB	0.22	0.00	0.57	0.38	0.81	0.78	0.97	0.97
5 dB	0.19	0.00	0.53	0.28	0.79	0.72	0.96	0.95

Figure 4 was prepared in the same manner as the charts displaying the effects of hearing loss configuration on the relative likelihood of effective speech communication. Although in this case the relative likelihoods were averaged across hearing loss configurations to display the effects of SRT elevation independent of hearing loss configuration. The pattern of results is quite different than that seen for hearing loss configurations. Proportional likelihoods decrease continuously as SRT elevation increases, rather than dropping steeply, as they did for the most severe hearing loss configurations. Note also that raised and loud vocal efforts are not as effective in maintaining high proportional likelihoods of effective speech communication as SRT elevation increases.



	0 dB	1 dB	2 dB	3 dB	4 dB	5 dB
Normal	1.00	0.78	0.57	0.44	0.34	0.29
Raised	1.00	0.94	0.87	0.81	0.73	0.64
Loud	1.00	0.96	0.93	0.90	0.87	0.84
Shouted	1.00	1.00	0.99	0.99	0.97	0.96

Figure 4. Proportional likelihoods of effective speech communication at 0.5 meters for different vocal efforts and SRT elevations.

Effects of SRT elevation: 1.0 meter communication distance

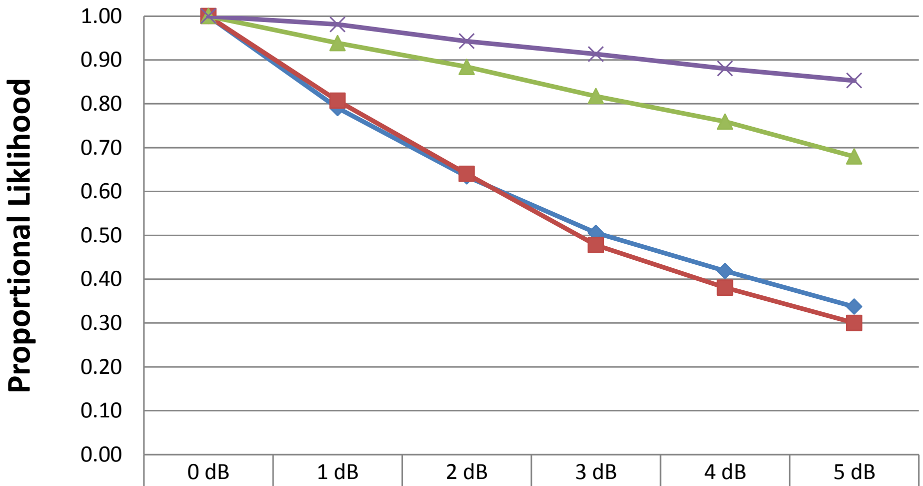
Table 18 shows the range of likelihoods of effective speech communication due to hearing loss configuration for each level of SRT elevation when normal, raised, loud, and shouted vocal efforts are used to communicate at a distance of 1 meter.

Table 18. Absolute likelihoods of effective speech communication at 1.0 meter for different vocal efforts and SRT elevations.

SRT elevation	Normal		Raised		Loud		Shouted	
	Max	Min	Max	Min	Max	Min	Max	Min
0 dB	0.16	0.00	0.48	0.24	0.77	0.72	0.95	0.95
1 dB	0.14	0.00	0.42	0.16	0.73	0.66	0.94	0.92
2 dB	0.11	0.00	0.37	0.12	0.70	0.61	0.90	0.88
3 dB	0.09	0.00	0.32	0.03	0.65	0.56	0.88	0.85
4 dB	0.07	0.00	0.28	0.02	0.61	0.48	0.84	0.82
5 dB	0.05	0.00	0.23	0.01	0.57	0.37	0.82	0.78

Again, the likelihoods are not exceedingly high except when speech is shouted. As with the previous table, maximum likelihoods are associated with normal pure-tone thresholds (0 F) and minimum likelihoods are associated with the most severe hearing loss configuration (70 S).

Figure 5 displays the proportional likelihoods of effective speech communication at a distance of 1.0 meter for the range of vocal efforts used in the previous analyses. The effect of increasing the communication distance from 0.5 to 1.0 meter lowered the proportional likelihoods so that shouted speech at 1.0 meter became similar to that of loud speech at 0.5 meter. Likewise, loud speech became similar to raised speech at the shorter distance; and raised speech because similar to normal speech at the shorter distance. Consequently, the proportional likelihoods for normal and raised levels of vocal effort fell off rapidly in the same manner at the greater communication distance.



	0 dB	1 dB	2 dB	3 dB	4 dB	5 dB
Normal	1.00	0.79	0.63	0.51	0.42	0.34
Raised	1.00	0.81	0.64	0.48	0.38	0.30
Loud	1.00	0.94	0.88	0.82	0.76	0.68
Shouted	1.00	0.98	0.94	0.91	0.88	0.85

Figure 5. Proportional likelihoods of effective speech communication at 1.0 meters for different vocal efforts and SRT elevations.

Discussion

These analyses provide a number of important insights as to how hearing impairment affects the likelihood of effective speech communication throughout a Correctional Officer's routine day. First, it is evident that even Correctional Officers with normal pure-tone thresholds and normal SRTs are limited in the effectiveness of their speech communication because of high background noise levels.

Second, because of the high background noise levels, normal and raised levels of vocal effort are rarely loud enough to achieve effective speech communication with a high likelihood. This implies that loud or shouted levels of vocal effort must often be used, even at relatively short communication distances. As communication distances increase, Correctional Officers must rely on radios or other means of electronic communication.

Third, the proportional likelihood measures are perhaps most important in evaluation of the effects of hearing loss on the ability to perform the hearing-critical job functions of a Correctional Officer. These measures express the hearing impaired individual's ability to perform such functions relative to the abilities of individuals with normal hearing. Thus, they do not directly reflect the difficulties that even individuals with normal hearing encounter in the high background noise environments found in prisons. However, when individuals with normal hearing encounter situations where the likelihood of effective communication is reduced substantially, even small additional reductions caused by hearing impairment may compromise safety and effectiveness by an unacceptable amount.

Finally, there are substantial differences in the pattern of proportional likelihoods of effective communication associated with different hearing loss configurations, compared with the pattern seen for elevated SRTs. Increases in vocal effort to loud or shouted levels are sufficient to maintain likelihoods of communication for individuals with normal hearing and for all but those with the most severe hearing loss configurations. This occurs at both 0.1 and 1.0 meter communication distances, where proportional likelihoods of 0.90 or greater are seen almost universally for loud and shouted levels of vocal effort. These results stand to reason. In the uniformly high noise environments where hearing-critical job functions are performed, Correctional Officers must use high levels of vocal effort to produce speech loud enough to allow effective communication. In other words, both the high level noise and the high level speech are audible, even for individuals with impaired audibility, as determined from their elevated pure-tone thresholds.

These findings imply that elevated pure-tone thresholds are poor predictors of the likelihood of effective speech communication in a noisy workplace. The proportional likelihoods associated with elevated SRTs tell a different story. As SRTs become elevated, larger values of ESII are required for effective speech communication. The vocal effort required to overcome impaired audibility in prison noise environments is not adequate to increase the ESII enough to maintain high proportional likelihoods as SRT elevation increases. Thus, the likelihoods for loud and shouted speech decrease consistently with increasing SRT elevation, as compared with normally hearing individuals. For example, proportional likelihoods for loud and shouted speech drop below 0.90 in only 1 of the 24 analyses based on hearing loss configuration, while 12 of the 24 likelihoods for loud and shouted speech drop below this level in the analyses based on SRT elevation. These comparisons indicate that SRT elevation is a more sensitive indicator of reduced likelihood of effective speech communication that pure-tone threshold configuration.

Screening materials for hearing standard

The eleventh step in the research strategy was to specify screening materials for use in implementation of the hearing standard.

Background and rationale

The analyses in the preceding section indicate that elevation of the SRT is a more appropriate and sensitive measure of the effects of hearing impairment on the likelihood of effective speech communication throughout a Correctional Officer’s routine day than measures based on pure-tone threshold elevation. The Hearing In Noise Test (HINT) has been widely recognized as an appropriate test for obtaining SRTs for the purpose of functional hearing screening (Nilsson et al., 1994; Soli & Wong, 2008; Vermiglio, 2008; Laroche et al., 2003, 2005, 2008; Giguere et al., 2008, 2010; Goldberg, 2001).

Discussion

The HINT assessment protocol measures SRTs in four different test conditions, with the speech source always located in front of the subject being tested. These test conditions include Quiet, Noise Front, Noise Right, and Noise Left (Soli & Wong, 2008; Vermiglio, 2008). The three SRTs measured in noise allow the individual’s binaural hearing ability to be included in the assessment. The Composite SRT, which is a weighted combination of the Noise Front, Noise

Right, and Noise Left SRTs, can be used as the screening measure. Thus, the hearing screening criteria can be stated in terms of Composite SRT values for the HINT.

The published norms for the Composite SRT are expressed in terms of the signal/noise ratio (SNR) at the threshold for a large sample of otologically normal individuals (Soli, 2008; Soli & Wong, 2008; Vermiglio, 2008). The standard deviation of Composite SRTs for this sample is also reported (Soli & Wong, 2008; Vermiglio, 2008). The Composite SRTs for the norm sample are normally distributed, which means that hearing screening criteria can be expressed not only in terms of the elevation of the Composite SRT, but also in terms of the percentage of otologically normal individuals who are likely to obtain scores above or below the screening criteria.

Screening protocol and criteria for hearing standard

The twelfth step in the research strategy was to specify the screening protocol and screening criteria for the hearing standard.

Background and rationale

The data and analyses reported above that describe the effects of SRT elevation on the likelihood of effective speech communication throughout a Correctional Officer's routine day indicate that normal vocal effort does not result in effective speech communication, even at communication distances of 0.5 meter. Nor is raised vocal effort effective at distances in excess of 1.0 meter. Raised vocal effort is somewhat effective at 0.5 meter distances, as are loud and shouted vocal effort at both distances. However, effectiveness is limited: only loud and shouted vocal effort results in likelihoods of effective speech communication of 0.90 or greater at 0.5 meter distances, and only shouted vocal effort results in likelihoods of this magnitude at distances of 1.0 meter or greater.

These considerations indicate that SRT elevations having relatively small effects on the likelihood of effective speech communication should be used as screening criteria. This is because even individuals with normal SRTs do not have high likelihoods of effective speech communication in prison noise environments. At the same time, however, the screening criteria cannot be so restrictive that individuals with normal hearing are excluded. Both of these considerations can be satisfactorily addressed by selecting screening criteria that do not exclude individuals with normal hearing and that result in only small reductions in the likelihood of effective speech communication.

Protocol for hearing screening

The assessment protocol consists of the Hearing In Noise Test (HINT) (Nilsson et al., 1994; Vermiglio, 2008; Soli & Wong, 2008) administered in four test conditions, Quiet, Noise Front, Noise Right, and Noise Left. These test conditions are to be administered using the automated computer-based HINT test instrument with the TDH-39 headphones provided with the instrument. Ideally, testing should be done in a sound room; although a quiet room without visual distractions is acceptable if a sound room is not available. The complete headphone assessment protocol can usually be administered in less than 30 minutes. The test must be administered by a certified audiological technician, a certified nurse technician, a certified audiologist, or an ENT physician.

In each test a different list of 20 sentences is presented in random order in quiet or in the presence of the reference HINT noise. For tests in noise the presentation level of the noise remains fixed at 75 dB (A), and the level of each sentence is adjusted automatically by the test instrument, depending on whether the previous sentence was repeated correctly. The presentation level of the sentence is reduced if the previous sentence was repeated correctly, and increased if the previous sentence was repeated incorrectly. This adaptive procedure is used to determine the presentation level of each sentence in the list. The average presentation level of all sentences after the first four sentences defines the SRT for the test condition.

During a HINT test in noise, headphone signals for the left and right ears are processed to simulate the spatial location of the speech and noise sources. This simulation has been validated on multiple occasions (e.g., Soli & Wong, 2008). In the Noise Front condition, the speech and noise sources are co-located directly in front of the subject at a distance of 1 meter. In the Noise Right condition, the speech remains in front and the noise is located 90° to the right at a distance of 1 meter, and in the Noise Left condition, the speech remains in front and the noise is located 90° to the left at a distance of 1 meter.

During the 12 hours preceding administration of the hearing screening protocol, applicants are required to have no exposure to loud noise of any kind. The HINT test conditions should be administered according to the following protocol.

1. Read the written instructions from the HINT User Manual to the subject, and answer any questions the subject may have about the test.
2. Position the headphones on the subject, and inform the subject that testing will begin with a practice test.
3. Administer an entire 20-sentence practice test in the Quiet condition.
4. Answer any further questions the subject has after the practice test.
5. Administer an entire 20-sentence test list in the Quiet condition.
6. Administer an entire 20-sentence practice test using the Noise Front condition.
7. Inform the subject that three different tests in noise will be administered.
8. Administer an entire 20-sentence test list using the Noise Front condition.
9. Administer a different entire 20-sentence test list using either the Noise Right or Noise Left condition.
10. Administer a different entire 20-sentence test list using the remaining test condition (Noise Right or Noise Left).

The test instrument automatically selects a different sentence list each time a test is performed. This method of list selection should always be used. The test instrument will automatically display the SRTs for each test condition and the Composite SRT. The test instrument must be calibrated yearly, as with all audiological test instruments that use calibrated sound presentation levels. The calibration date is stored with the results of each HINT test. Test results obtained with an instrument that has not been calibrated within the last year are not acceptable and will need to be repeated.

Reporting requirements

Printed reports summarizing the test conditions and results, as well as information about the calibration of the instrument, can be produced after each applicant is tested. Two reports are required for each applicant, the Narrative Report and the Custom Report. The Narrative Report summarizes the applicants test results and gives information as to whether the applicant met the screening criteria. The Custom Report gives details about the applicant, the test conditions, and the calibration information. The following options should be selected for inclusion in the Narrative Report: basic demographic information, test site and calibration information, HINT scores in tabular form, and details of each test condition.

Hearing screening criteria

Two hearing screening criteria based on the HINT Composite SRT measured in noise and the SRT measured in quiet are specified. The screening criterion defined by the Composite SRT in noise is based on the need for effective speech communication in the background noise environments where hearing-critical job functions are performed throughout a Correctional Officer's routine day and during responses to incidents. The screening criterion based on the SRT measured in quiet is based on the additional need to understand soft and whispered speech, as well as speech originating from behind doors or through windows.

The screening criterion for effective speech communication in noise is based on the elevation of the applicant's HINT Composite SRT above the average for otologically normal individuals. The average Composite SRT, expressed as a speech-to-noise ratio or SNR, is -6.4 dB SNR which defines the norm for individuals with normal hearing (Soli & Wong, 2008). The screening criterion is a HINT Composite SRT **of -4.0 dB SNR** or less. By placing the screening criterion at 2.4 dB SNR above the norm, over 99% of otologically normal individuals are expected to obtain passing scores. SRTs in noise are to be measured with the noise level fixed at **75 dB (A)**. The screening criterion for speech communication in noise may also be expressed as a HINT composite threshold of **71 dB (A)** or less. The preceding analyses indicate that a hearing impaired applicant who fails to meet this screening criterion is likely to have at least 15% less effective speech communication in noise throughout a routine workday as a Correctional Officer, as compared with an otologically normal individual.

The hearing screening standard for speech communication in quiet is based on the average level of soft or whispered speech heard at a short distance, 30 dB (A) (Nilsson, 1992; Goldberg, 2001; Borden, 1984; Ostergaard, 1986). The hearing screening for speech communication in quiet is a HINT SRT in quiet of **27 dB (A)** or less. Over 99% of otologically normal individuals are also expected to obtain passing scores with this screening criterion.

Applicants who fail to meet either or both of the screening criteria may elect to be retested. Only the failed criteria need to be retested. Retesting should be done immediately after initial testing during the same visit. Figure 6 displays a flowchart summarizing the retesting procedure. Applicants are accepted who meet both of the screening criteria during the initial headphone HINT tests. Applicants who fail to meet either or both of the screening criteria can be retested. If they pass the retest they are accepted. If they fail again on the retest they are rejected.

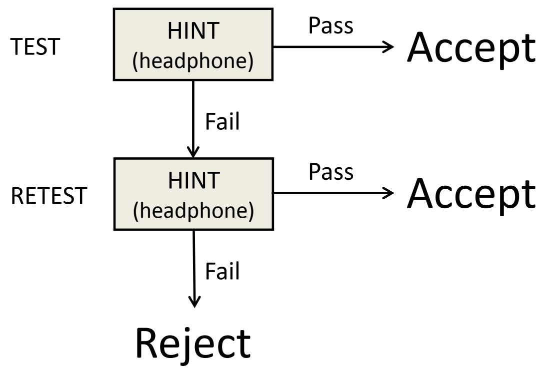


Figure 6. Test-retest procedure for applicants who fail to meet either or both of the screening criteria.

Discussion

Two hearing screening criteria based on the HINT Composite SRT in noise and the quiet SRT have been defined. Both screening criteria include at least 99% of otologically normal individuals. The criterion defined by the SRTs measured in noise addresses the ability to achieve effective speech communication throughout a routine workday. The criterion defined by the SRT measured in quiet addresses the ability to understand soft and whispered speech.

Evaluation of auditory prostheses

The thirteenth step in the research strategy was to evaluate the use of auditory prostheses by Correctional Officers.

Background and rationale

Applicants for the job of Correctional Officer may require the use of one or two auditory prostheses, such as hearing aids, to meet the hearing screening criteria established by the hearing standard. In this case, it will be necessary for the individual to wear and use their prostheses at all times on the job. This requirement raises the question of whether there are requirements for the job of Correctional Officer that cannot be met by individuals with auditory prostheses. Of special concern was the use of protective headgear. It was important to determine if this headgear might dislodge the prostheses while being donned and/or might interfere with the proper function of prostheses. Research staff addressed these issues in several ways as described below.

Methodology

The research team interviewed 15 additional Correctional Officers in three separate interviews to determine the type of equipment used on the job that might affect a Correctional Officer's use of auditory prostheses. This information was supplemented by a written survey of all the prisons to determine the frequency and criticality of protective headgear use. In addition, research staff conducted an informal survey of technology experts from the hearing aid industry to determine their views on whether current hearing aid technologies will function properly when worn under protective headgear.

Results

The interviews with SMEs revealed that Correctional Officers use three types of protective headgear during responses to incidents: gas masks, protective face shields, and riot or cell extraction helmets. A Correctional Officer wearing all three types of protective headgear is shown in Figure 7. The following information describes each type of protective headgear and its potential effects on the use of auditory prostheses.

Figure 7. Correctional Officer wearing a gas mask, protective face shield, and riot helmet.

Gas masks

The gas mask is worn over the face with an adjustable rubber strap around the back of the head to hold it in place. Use of a gas mask is mandatory in nearly 90% of incident responses when chemical agents may be expelled. Incidents calling for the use of a gas mask include cell extractions, riots, skirmish lines, and yard fights.

Rapid donning of a gas mask may dislodge prostheses, but once donned the gas mask does not affect the performance of the prosthesis because the area around the ear is not covered by the gas mask. However, these masks do affect the clarity and level of speech when worn, increasing the difficulty of effective speech communication even for otologically normal individuals.

Protective face shields

The protective face shield is attached to the riot/cell extraction helmet and worn over the face. The face shield covers the mouth and thus attenuates the level of speech, again making effective speech communication difficult for all Correctional Officers, even those who are otologically normal.

Riot helmets

The helmets worn during riots and cell extractions cover the ear entirely and fit tightly. There are two kinds of helmets. One has no ear hole and heavy padding surrounding the ear. The other has several small ear holes, no padding, and the portion of the helmet covering the ear is held tightly over the ear with a chinstrap. Both helmets are fabricated from heavy plastic.

When helmets are worn during anticipated responses (planned use) to situations such as cell extractions, Correctional Officers have time to don the helmet carefully. However, when helmets are worn in response to unanticipated incidents such as yard fights and riots, officers have little time to prepare and must don the helmet quickly, often while running.

Any hard surface that reflects sound, such as the material used in helmets, can cause a hearing aid to become unstable and howl or whistle from acoustic feedback when the surface is close to the hearing aid's microphone. Once a riot helmet is donned, the hard shell of the helmet is in close proximity to the ear, creating a situation where feedback is likely to occur. Once a hearing aid is in unstable feedback, it ceases to function properly. A Correctional Officer wearing hearing aids under a riot helmet during a response to an incident may not be able to remove the helmet to adjust the hearing aids without endangering himself or herself and other Correctional Officers.

The research staff gathered additional information about the extent of helmet use throughout the state prison system by sending a written survey to each facility. All 33 facilities provided information about the frequency of helmet use at their particular institution. The following is a summary of these responses.

- Percent of facilities using helmets more than once per year: 61%
- Percent of facilities using helmets more than once per month: 33%
- Percent of helmet use in anticipated responses, such as cell extractions, where there is time to carefully don a helmet: 36%
- Percent of helmet use in unanticipated responses to incidents such as riots and yard fights, where the helmet must be donned "on the run:" 64%

The research team also conducted a supplemental telephone survey to learn whether helmets could be specially modified so that hearing aids might function properly under the helmet. The majority of respondents said a Correctional Officer would be more susceptible to injury if the ears were not covered by ear protection flaps. The survey asked additional questions about the feasibility of assigning specialized helmets to Correctional Officers with hearing aids. All of the respondents stated the Correctional Officers are not assigned a specific helmet for their singular use, and the majority of respondents said it would not be feasible to have special helmets assigned to individuals. Helmets and other protective gear are stored at strategic locations so that nearby Correctional Officers can respond quickly by using whatever particular protective gear is available at the location. Moreover, assigned posts for Correctional Officers can change routinely and unpredictably within shifts and from day to day, making it impractical to pre-stock special helmets at particular strategic locations in anticipation that a Correctional Officer with hearing aids will be posted to that location at a specific day and time.

Survey of hearing aid technologies

The research team pursued further the question of whether current advanced hearing aid technology is robust enough to ensure that hearing aids will function properly and not cause acoustic feedback problems when worn under a riot helmet. The research staff contacted technical experts at the six leading hearing aid manufacturers throughout the world and asked whether their technology for feedback control and cancellation would be effective under a riot helmet.

Most of the experts stated that riot helmets are likely to create significant acoustic feedback problems, especially using unpadded helmets. However, there were many qualifying considerations, such as the type of hearing loss, the severity of hearing loss, the amount of hearing aid amplification, and the details of the feedback cancellation technology. These many considerations make it impossible to predict if a particular applicant's hearing aids would or would not function properly when worn under a riot helmet.

Discussion

The evidence from SME interviews and surveys, together with the information provided by technical experts in the hearing aid industry, lead to several conclusions. Of the types of protective headgear that Correctional Officers are required to wear, riot helmets are of greatest concern for Correctional Officers with hearing aids. However, all Correctional Officers must be prepared to don riot helmets in response to both anticipated and unanticipated incidents. During the response to an unanticipated incident, it may be necessary to don riot helmets quickly in a manner that could dislodge an auditory prosthesis. When a riot helmet is worn by a Correctional Officer with hearing aids, there is a real risk that the hearing aids will not function properly because of acoustic feedback. Technical experts from throughout the hearing aid industry were unable to assure that hearing aids would function properly under a riot helmet.

Although the frequency of riot helmet use during anticipated and unanticipated incidents varied across facilities throughout the state, a significant number of facilities use riot helmets more than once per month and many of the incidents requiring helmet use are unanticipated. Since Correctional Officers must be available for assignment to any facility, it is impossible to consider assignment of Correctional Officers with hearing aids to facilities where riot helmets are not used. These considerations point to the need for supplemental screening criteria. These supplemental screening criteria can be used on a case-by-case basis to determine whether an applicant who meets the hearing screening criteria is able to use his or her auditory prostheses effectively while donning and wearing a riot helmet. The final section of the research strategy addresses this consideration.

Supplemental screening protocol for applicants with auditory prostheses

The final step in the research strategy was to supplement the screening protocol for use in screening individuals with auditory prostheses.

Background and rationale

The evidence that Correctional Officers must be able to don and use riot helmets in response to both anticipated and unanticipated incidents indicates that supplemental screening is required for those applicants who use auditory prostheses. Supplemental screening is not required for those applicants who fail to meet the hearing screening criteria with their auditory prostheses. The supplemental screening must verify that riot helmets can be readily and quickly donned, as required in response to unanticipated incidents, without dislodging the prostheses, and that the prostheses function properly when worn under the helmet.

Supplemental screening protocol

Supplemental screening should be administered by an audiologist experienced with the type of auditory prostheses used by the applicant. The supplemental screening protocol for applicants with auditory prostheses consists of several steps. Figure 8 displays a flowchart summarizing each step.

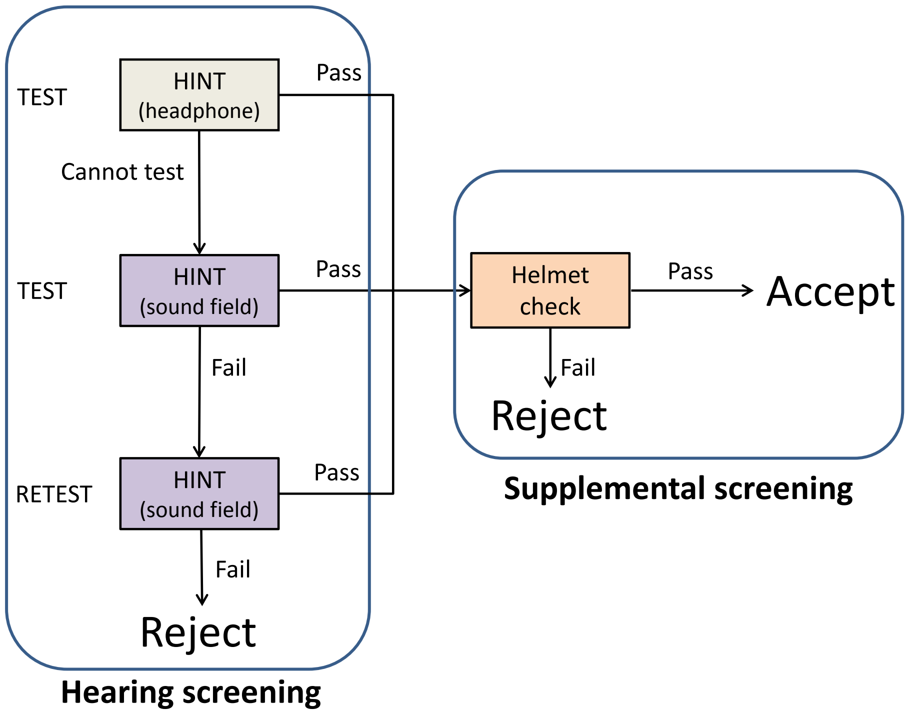


Figure 8. Flowchart summarizing hearing screening and supplemental screening for applicants with auditory prostheses.

Headphone screening

Prior to administration of the HINT screening protocol, the audiologist must verify that the prostheses are functioning properly and adjusted to physiologically appropriate settings. If the applicant meets the hearing screening criteria when tested with the basic protocol using the TDH-39 headphones, then the applicant must next perform a helmet check. Applicants who fail to meet either or both of the screening criteria can be retested. If they pass the retest they must next perform a helmet check. If they fail again on the retest they are rejected.

The helmet check is used to determine whether the helmet can be donned without dislodging the prostheses and, in the case of hearing aids, to determine whether they continue to function properly without acoustic feedback when worn under the helmet. If both of these conditions are satisfied, the applicant is accepted. In this case, the applicant will be required to wear their prostheses at all times on the job. If either or both of the conditions are not satisfied, the applicant is rejected.

Sound field screening

In the event an applicant with hearing aids cannot be tested with the headphones because of acoustic feedback caused by the headphones, the applicant can be tested in the sound field using loudspeakers rather than headphones. Sound field HINT testing is done with the same protocol as headphone HINT testing. Applicants who meet both of the screening criteria during the initial sound field HINT tests must next perform a helmet check. Applicants who fail to meet either or both of the screening criteria can be retested. If they pass the retest they must next perform a helmet check. If they fail again on the retest they are rejected.

Sound field testing must be conducted by an audiologist at a facility with a sound room large enough to conduct the screening protocol in the sound field. Again, the audiologist must verify that the prostheses are functioning properly and adjusted to physiologically appropriate settings. Evidence that the loudspeakers in the sound room have been calibrated within the last year and that the HINT norms have been appropriately adjusted for sound field testing must also be provided together with the printed report summarizing the test results.

The screening criterion for the sound field HINT are the same for the Quiet SRT, 27 dB (A) or less. However, the criterion for the composite SRT must be based on the *adjusted* sound field composite SRT, and not on the headphone composite SRT. This *adjusted* criterion is defined as the SNR 2.4 dB above the *adjusted* sound field composite HINT norm. The HINT test instrument automatically incorporates adjustments to the sound field norms after data have been input to achieve the appropriate adjustments.

If the Quiet SRT or the Composite SRTs measured in a sound field fail to meet the screening criteria, the applicant can be retested in the sound field. If either criterion is not met during retesting, the applicant is rejected. If the sound field Quiet SRT and the sound field Composite SRTs meet the screening criteria, either on the initial test or on retest, the individual must undergo the same helmet check described above. If the helmet can be donned without dislodging the prostheses and if the prostheses, in the case of hearing aids, continue to function properly without acoustic feedback when worn under the helmet, the applicant is accepted. Again, the applicant will be required to wear their prostheses at all times on the job. If either or both of the conditions are not satisfied, the applicant is rejected.

Discussion

If an applicant for the job of Correctional Officer is unable to don and wear a regular issue riot helmet because their auditory prostheses are dislodged or do not function properly under the helmet when helmets are required, then the prostheses do not allow the individual to perform all the necessary job functions of a Correctional Officer. A Correctional Officer who cannot wear a riot helmet constitutes a health and safety risk that is inconsistent with the paramount public safety requirements of the job.

For these reasons, it is essential that individuals who meet the hearing screening criteria, either with headphones or in sound field testing, undergo the helmet check procedure described above. The helmet check must be done by an audiologist or other specialist who has experience with the function and performance of the specific auditory prostheses used by the applicant. This evaluation should include a determination of whether, in the case of hearing aids, audible acoustic feedback is observed while the helmet is worn.

If the applicant meets the hearing screening criteria while using their prostheses and the prostheses function properly when worn under the riot helmet, the applicant is accepted. Individuals who meet the screening criteria in this manner will be required to maintain their prostheses in working condition and use them on the job at all times.

The State should bear the cost of administering the headphone screening protocol, as well as the cost of administering additional sound field screening in cases where considerations related to the use of auditory prostheses arise. Applicants who fail to meet the screening criteria and who wish to provide additional information about their functional hearing ability relevant to their application may do so at their own expense.

Bibliography

1. American Educational Research Association, American Psychological Association, & National Council on Measurement in Education. (1999). Standards for educational and psychological testing. Washington, D. C.

2. American National Standards Institute (2007). Methods for calculation of the speech intelligibility index. ANSI S3.5-1997 (Reaffirmed in 2007). New York: American National Standards Institute.

3. Barrenäs, ML, & Holgers, KM (2000). A clinical evaluation of the hearing disability and handicap scale in men with noise induced hearing loss. Noise & Health 6: 67-78.

4. Begines, T (1995) Fitness and risk evaluation. Spectrum 121:9–11. Cook LE, Hickey MJ. (2003) Physical hazards and noise in law enforcement. Clinical Occupational Environmental Medicine 3:419–442.

5. Bentler, RA (2000). List equivalency and test-retest reliability of the Speech in Noise test. American Journal of Audiology, 9(2):84-100.

6. Bilger, RC, Nuetzel, JM, Rabinowitz, WM & Rzeczkowski, C (1984). Standardization of a test of speech perception in noise. Journal of Speech and Hearing Research, 27:32-48.

7. Brannick, MT, Levine, EL., Morgeson, FP (2007). Job and work analysis. Thousand Oaks, CA: Sage Publications.

8. Bronkhorst, AW, & Plomp, R (1988). The effect of head-induced interaural time and level differences on speech intelligibility in noise. Journal of the Acoustical Society of America. 83(4):1508-16.

9. Bronkhorst, AW, & Plomp R, (1989). Binaural speech intelligibility in noise for hearing-impaired listeners. Journal of the Acoustical Society of America. 86(4):1374-83.

10. Bronkhorst, AW, & Plomp, R (1992). Effect of multiple speech like maskers on binaural speech recognition in normal and impaired hearing. Journal of the Acoustical Society of America. 92(6):3132-9.

11. Coles, RRA, and Sinclair, A (1988). Hearing. In Fitness for Work. The Medical Aspects. Edwards, FC, McCallum, RI & Taylor, PJ(eds). Oxford, Oxford University Press.

12. Cord, MT, Walden, BE, Atack, RM (1992). Speech recognition in noise test (SPRINT) for H-3 profile. Walter Reed Army Medical Center.

13. Cox, RM, Alexander, GC, Gilmore, C, & Pusakulich, KM (1988). Use of the Connected Speech Test (CST) with hearing-impaired listeners. Ear & Hearing, 9(4):198-207.

14. Dobie, RA, and Sakai, CS (2001). Estimation of hearing loss severity from the audiogram. In D Henderson, D Prasher, R Kopke, R Salvi, and R Hamernik (Eds.), Noise induced hearing loss basic mechanisms, prevention and control. London, England: Noise Research Network Publications.

15. Duquesnoy, AJ, & Plomp, R (1983). The effect of a hearing aid on the speech-reception threshold of hearing-impaired listeners in quiet and in noise. Journal of the Acoustical Society of America 73(6): 2166-2173.

16. Duquesnoy, AJ (1983). Effects of a single interfering noise or speech source upon the bin-aural sentence intelligibility of aged persons, Journal of the Acoustical Society of America74, 739-743.

17. Festen, JM, & Plomp, R (1986). Speech-reception threshold in noise with one and two hearing aids. Journal of the Acoustical Society of America 79(2): 465-471.

18. Festen, JM, & Plomp, R (1990). Effects of fluctuating noise and interfering speech on the speech-reception threshold for impaired and normal hearing. Journal of the Acoustical Society of America. 88(4):1725-36.

19. Forshaw, S, & Hamilton, K (1997). Assessment of occupational hearing requirements. Canadian Acoustics 25: 3-9.

20. Forshaw, S, Ritmiller, R, Hodgson, M, Laroche, C, (1999) Estimates of speech intelligibility based on equivalent speech- and noise-spectrum levels and hearing thresholds. Canadian Acoustics 27: 112-113.

21. Giguère, C, Laroche, C, Soli, SD, and Vaillancourt, V (2008). Functionally-based screening criteria for hearing-critical jobs based on the Hearing In Noise Test. International Journal of Audiology, 47, 319-328.

22. Giguère, C, Laroche, C, Vaillancourt, V, Soli, SD (2010). Modeling speech intelligibility in the noisy workplace for normal-hearing and hearing-impaired listeners using hearing protectors. International Journal of Acoustics and Vibration 15: 156-167.

23. Goldberg, RL (2001). Hearing Guidelines for the California Commission on Peace Officer Standards and Training.

24. Guion, RM (1998). Assessment, measurement, and prediction for personnel decisions. Mahwah, NJ: Lawrence Erlbaum Associates.

25. Houtgast, T, & Festen, JM (2008). On the auditory and cognitive functions that may explain an individual's elevation of the speech reception threshold in noise. International Journal of Audiology 47:287-295.

26. Kales, SN, Aldrich, JM, Polyhronopoulos, GN, Artzerounian, D, Gassert, T, Hu, H, Kelsey, K, Sweet, C, Christiani, DC (1998). Fitness for duty evaluations in hazardous materials firefighters. Journal of Occupational and Environmental Medicine 40:925–931.

27. Kalikow, DN, Stevens, KN & Elliott, LL (1977). Development of a test of speech intelligibility in noise using sentence materials with controlled word predictability. Journal of Acoustical Society of America, 61(5):1337-51.

28. Killion, M, & Niquette, PA (2000). What can the pure-tone audiogram tell us about a patient's SNR loss? Hearing Journal 53: 46-53.

29. Kramer, SE, Kapteyn, TS, Houtgast, T (2006). Occupational performance: comparing normally-hearing and hearing-impaired employees using the Amsterdam Checklist for Hearing and Work. International Journal of Audiology 45:503–512.

30. Laroche, C, Giguère, C, Soli, SD, Vaillancourt, V (2008). Establishment of fitness standards for hearing-critical jobs. In: Proceedings of the 9th Congress of the International Commission on the Biological Effects of Noise as a Public Health Problem, Mashantucket, CT. Dortmund, Germany.

31. Laroche, C, Giguère, C, Vaillancourt, V & Soli, SD (2005). Development and validation of hearing standards for Canadian Coast Guard Seagoing Personnel and C&P and land-based personnel. Phase II, Final report to Department of Fisheries and Oceans under Contract No. F7053-000009.

32. Laroche, C, Soli, SD, Giguère, C, Lagace´, J, Vaillancourt, V, Fortin, M (2003). An approach to the development of hearing standards for hearing-critical jobs. Noise and Health 6:17–37.

33. Laroche, C (1994). Cases of possible job discrimination based on hearing loss. Canadian Acoustics 22: 89-90.

34. MacLean, S (1995). Employment criteria in hearing critical jobs. Spectrum 12:20–23.

35. MacLean, S (2001). A practical approach to workplace communication assessment: or ‘‘keep your head down and your ears open.’’ NHCA Spectrum 18:12–13.

36. MacLean, S, Danielson, R (1996). Hearing standards in the U.S. military. Spectrum 13:16–17.

37. MacLean, S, Nilsson M (1997). Hearing critical jobs. Spectrum 14.

38. Middleweerd, MJ, Festen, JM, Plomp, R (1990). Difficulties with speech intelligibility in noise in spite of a normal pure-tone audiogram. Audiology 29:1–7.

39. Morata, TC, Themann, CL, Randolph, RF, Verbsky, BL, Byrne, DC, Reeves, ER (2005). Working in noise with a hearing loss: perceptions from workers, supervisors, and hearing conservation program managers. Ear & Hearing 26:529–545.

40. National Institute for Occupational Safety and Health (1998). Criteria for a recommended standard : Occupational noise exposure, Revised criteria 1998. Cincinnati, OH : Centers for Disease Control and Prevention.

41. Nilsson, M, Soli, SD, Sullivan, JA (1994). Development of the Hearing in Noise Test for the measurement of speech reception thresholds in quiet and in noise. Journal of the Acoustical Society of America 95:1085–1099.

42. Parving, A & Ostri, B (1983). On objective criteria for hearing impairment and hearing disability. Scandinavian Audiology 12: 165-169.

43. Pavlovic, CV, Studebaker, GA and Sherbecoe, RL (1986). An articulation index based procedure for predicting the speech recognition performance of hearing-impaired individuals. Journal of the Acoustical Society of America 80: 50-57.

44. Pearsons, KS, Bennett, RL & Fidell, S (1977). Speech Levels in Various Noise Environments. EPA-600/1-77-025, US Environmental Protection Agency.

45. Philippon, B, Giguere, C & Laroche, C (2004). Objective predictions of the performance intelligibility function for speech perception in different noise environments using the SII index. Technical report, Hearing Research Laboratory, University of Ottawa.

46. Plomp, R, & Mimpen, AM (1979). Speech-reception threshold for sentences as a function of age and noise level. Journal of the Acoustical Society of America. 66(5):1333-42.

47. Plomp, R (1978). Auditory handicap of hearing impairment and the limited benefit of hearing aids. Journal of the Acoustical Society of America 63:533–549.

48. Plomp, R, & Mimpen, AM (1979). Improving the reliability of testing the speech reception threshold for sentences. Audiology, 18:43-52.

49. Plomp, R (1986). A signal-to-noise ratio model for the speech-reception threshold of the hearing impaired. Journal of Speech and Hearing Research 29: 146-154.

50. Plomp, R, and Mimpen, AM (1981). Effects of the orientation of the speaker's head and the azimuth of a noise source on the speech-reception threshold for sentences. Acustica 48, 325-328.

51. Rhebergen, KS, Versfeld, NJ (2005). A speech intelligibility index-based approach to predict the speech reception threshold for sentences in fluctuating noise for normal-hearing listeners. Journal of the Acoustical Society of America 117:2181-92.

52. Rhebergen, RS, Versfeld, NJ & Dreschler, WA (2006). Extended speech intelligibility index for the prediction of the speech reception thresholds in fluctuating noise. Journal of the Acoustical Society of America 120:3988-3997.

53. Rhebergen, KS, Versfeld, NJ, Dreschler, WA (2008). Prediction of the intelligibility for speech in real-life background noises for subjects with normal hearing. Ear & Hear: 29 169-172.

54. Smoorenburg, GF (1992). Speech reception in quiet and in noisy conditions by individuals with noise-induced hearing loss in relation to their tone audiogram. Journal of the Acoustical Society of America 91:421-37.

55. Society for Industrial and Organizational Psychology (2003). Principles for the validation and use of personnel selection procedures. Bowling Green, OH

56. Soli, SD (2003). Hearing and job performance. Paper commissioned by the Committee on Disability Determination for Individuals with Hearing Impairment, National Research Council, National Academy of Sciences.

57. Soli, SD, & Vermiglio, A (1999). Assessment of functional hearing abilities for hearing-critical jobs in law enforcement. Report for the California Peace Officers Standards and Training Commission.

58. Soli, SD (2008). Some thoughts on communication handicap and hearing impairment. International Journal of Audiology, 47, 285-286.

59. Soli, SD, and Nilsson, MJ (1994). Assessment of communication handicap with the HINT, Hearing Instruments 45, 12-16.

60. Soli, SD, and Wong, L (2008). Assessment of speech intelligibility in noise with the Hearing In Noise Test. International Journal of Audiology, 47, 356-361.

61. Tufts, JB, Visal, KA, Briggs, S (2009). Auditory fitness for duty: A review. Journal of the American Academy of Audiology 20: 539-557.

62. U.S. Department of Labor. (2007) Medical examinations and inquiries specifically permitted. Regulations to implement the equal employment provisions of the Americans with Disabilities Act. 29 C.F.R. 1 1630.14. Washington, DC: U.S. Government Printing Office.

63. Vermiglio, AJ (2008). The American English Hearing In Noise Test. International Journal of Audiology, 47, 386-387.

Appendix A: Department of Personnel job description for Correctional Officer

Correctional Officer

Under supervision as a sworn peace officer, to provide the public protection by enforcing State and Federal laws and administrative regulations while supervising the conduct of inmates or parolees of a State correctional facility or camp; and to do other related work.

Distinguishing characteristics

The Correctional Officer class is an entry level and training class. Persons selected as Correctional Officers undergo a formal, six-week training program at the California Department of Corrections ' Training Academy and a formal two-year apprenticeship program. The apprenticeship program requires satisfactory completion of a minimum of 3,600 hours (two years) of experience in the designated work process categories.

In carrying out the primary duty of public protection, the Correctional Officer class performs duties that vary among institutions and among designated posts within an institution due to varying security levels of inmates, design of correctional facilities, geographical location, watch assignment, and the number of inmates. Assignments for this class include duty in towers, housing units, reception centers, kitchens, outside crew supervision, search and escort, control booths, yard, gun posts, and transportation.

Typical tasks

In a correctional institution, conservation center, camp, parole facility, or other custodial assignment: disarms, subdues and applies restraints to an inmate; runs to the scene of a disturbance or emergency; supervises the conduct of inmates or parolees in housing units, during meals and bathing, at recreation, in classrooms, and on work and other assignments, and escorts them to and from activities; stands watch on an armed post or patrols grounds, quarters, perimeter security walls and fences, or shops; walks or stands for long periods of time; runs up or down stairs; maintains visual surveillance of institutional grounds from observation tower or central security area; defends self against an inmate armed with a weapon; listens for unusual sounds that may indicate illegal activity or disturbances such as whispering, scuffling, or rattling of chain link fence; watches for indications of illegal activity or disturbance in relative darkness or in normal lighting; reads daily journal, facility rules, procedures, regulations, post orders, and other formal written materials relevant to job performance; writes various reports, memoranda, and correspondence; oversees the work of a group of inmates detailed to mechanical or industrial operations, or to farm, maintenance, or other activities; escorts inmates or parolees on trips or other movements outside institution or facility grounds; operates motor vehicles to perform routine and emergency transport of inmates; takes periodic counts of inmates; prepares count slips for all types of counts and clears counts with control; inspects quarters of inmates for contraband, and checks on sanitary conditions and orderliness; conducts clothed/unclothed body searches; examines incoming and outgoing mail; promotes acceptable attitudes and behavior of inmates or parolees; grades inmates on conduct and productivity; acts as entrance gate officer and searches visitors and transport vehicles for contraband, admits visitors with proper credentials; supervises visits to inmates, and escorts visitors through the institution facilities; reports infractions of rules and regulations and irregular and suspicious occurrences, and takes or recommends appropriate action; prevents escapes and injury by inmates or parolees to themselves, employees, and to property; searches for and recaptures escaped inmates; carries, lifts, or drags heavy objects such as a disabled or unconscious inmate/staff; performs patrol duties primarily by vehicle and foot patrols; conducts criminal and administrative investigations; receives, checks, and issues guns, ammunition, and other supplies and equipment; keeps firearms in good working condition; fires weapons in combat/emergency situations; and may perform noncustodial duties as a minor part of a custodial assignment.

Minimal qualifications

Education: Equivalent to completion of the twelfth grade.

[Twelfth grade equivalence: Equivalence to the completion of the twelfth grade may be demonstrated by: (1) possession of a high school diploma issued by a U. S. institution; or (2) passing the California High School Proficiency test; or (3) passing the General Education Development test indicating high school graduation level; or (4) receiving a college degree from an accredited two- or four-year college.]

Knowledge and abilities

Knowledge of: Purposes and methods of discipline as applied to persons in custody; duties of a Correctional Officer; correct grammar and spelling; proper use and care of firearms; basic arithmetic.

Ability to: Control, direct, and instruct inmates or parolees individually and in groups; remember names and faces; interpret and enforce institutional rules and regulations with firmness, tact, and impartiality; read and interpret written material accurately and rapidly; write effectively; prepare accurate and objective written reports using good grammar, composition and correct spelling; promote socially acceptable attitudes and behavior of inmates or parolees; rate the conduct and productivity of inmates or parolees accurately and impartially; think and act quickly in emergencies; reason logically and communicate effectively; make simple arithmetic computations; correctly follow oral/written directions; accept the requirements of the Department and institution; accurately distinguish inmates and correctional staff from a tower or elevated position; accept role as authority figure; make appropriate use of disciplinary options; deal tactfully and professionally with the public, inmates, and staff; willingness to follow chain of command; climb ladders and stairwells on a routine and emergency basis; see in dim/bright light situations; operate departmental vehicles and equipment, including firearms and mobile radio; physically perform a variety of tasks including carrying accident victims and subduing combative inmates; analyze situations accurately and adopt an effective course of action; and make satisfactory progress in the prescribed academic and practical work in an approved apprenticeship program for the Correctional Officer.

Special personal characteristics

Emotional maturity and stability; sympathetic and objective understanding of persons in custody; satisfactory record as a law-abiding citizen; leadership ability; tact; good personal and social adjustment for correctional work; neat personal appearance; courage; alertness; willingness to work day, evening, or night shifts, weekends, and holidays, and to report for duty at any time emergencies arise.

Minimum age for appointment - 21 years.

Special physical characteristics

Good physical health; sound mental and emotional condition; freedom from physical or mental condition that would interfere with the full performance of the duties of a Correctional Officer; strength, endurance and agility; hearing sufficient to perform the essential functions of the job; a corrected visual acuity of 20/20 or better in each eye, an uncorrected visual acuity of 20/60 or better in each eye, ability to pass a color vision test comparable to the Farnsworth 0 - 15 without the use of an X- Chrome lens or other colored filters, and a peripheral field of view of at least 120 degrees of horizontal extent and 100 degrees of vertical extent with no evidence of scotomas (non-seeing areas) within the full visual field of each eye.

Special requirements

Government Code 1029 provides that persons convicted of a felony are disqualified from employment as peace officers. Such persons are not eligible to compete for, or be appointed to, positions in this class.

Government Code 1029.1 requires that a thorough background investigation be completed prior to appointment date. Persons unsuccessful in the investigation cannot be appointed as a peace officer.

Government Code 1031 (f) provides that any physical and psychological suitability examinations administered be completed prior to appointment date. Persons who are not successful in these examinations cannot be appointed as a peace officer.

Government Code 1031 (c) provides that a candidate for a peace officer position be fingerprinted for search of local, State, and national fingerprint files to disclose any criminal record. Any person prohibited by State or Federal law from possessing, using or having in his/her custody or control any firearm, firearm device, or other weapon or device authorized for use by the California Department of Corrections is not eligible to compete for, be appointed to, or continue employment in this classification.

Citizenship requirements

Pursuant to Government Code Section 1031 (a), in order to be a peace officer a person must be either a U. S. Citizen or be a permanent resident alien who is eligible for and has applied for U. S. Citizenship. Any permanent resident alien who is employed as a peace officer shall be disqualified from holding that posit i on if his/her application for citizenship is denied.

Drug testing requirement

Applicants for positions in this class are required to pass a drug screening test. (The drug screening test will be waived for employees who are currently in a designated "Sensitive" class for which drug testing is required under State Personnel Board Rule 213.)

Appendix B: Example of an incident report

On April 5, 2008 at approximately 0835 hours, while assisting with cell feeding the morning meal, I heard Inmate X complaining that he did not receive his breakfast tray. I approached the cell and told Inmate X that he did not receive his tray because he refused it. Inmate X then stated "This is why cops get hurt, why you guys are always getting pounded on, I'll hurt you mother *******!" In order to stop Inmate X's attempt to incite the other inmates in the housing unit I ordered Inmate X to cuff up and he complied by placing his hands through the food tray slot. I placed Inmate X in handcuffs. As I was escorting Inmate X out of the building, he continued to incite other inmates by shouting. As Inmate X and I exited the housing unit C2, Inmate X became resistive and attempted to pull away from my grasp. Officer X responded to assist me. Inmate X then lowered his left shoulder and charged Officer X and striking him in the chest, knocking him off balance. I gained compliance of Inmate X by grabbing him with my left hand on his right wrist and my right hand on his shoulder and guided him to the ground utilizing my body weight. I performed a clothed body search with negative results for weapons or contraband. Responding staff took control of Inmate X and escorted him to the facility C Program office.

Appendix C: Tabular summaries of incident report analyses

Based on the stratified sampling plan, the research team analyzed 275 incident reports. The most frequent incident report categories and their combinations with facility location, shift, and the cue for the incident were determined.

Simple Tabulations of Incident Report Analysis

Table C-1 tabulates the incident report categories. Incidents involving non-assaultive/oppositional behavior were most prevalent, followed by physical assault/battery/altercation one-on-one.

Table C-1. Incident Report Categories

Incident Report Category	Percentage
Contraband	13.5%
Medical Intervention	04.4%
Physical Assault/Battery/Altercation One-on-one	19.6%
Physical Assault/Battery/Altercation Group	08.0%
Non-Assaultive/Oppositional Behavior	28.4%
Unusual/Abhorrent Behavior	04.7%
Suicide, Suicide Threat, Suicide Attempt/Self-Injury	03.6%
Miscellaneous	14.2%
Multiple Elements	03.6%

Table C-2 reports the percentage of incidents as a function of watch. Incidents were spread over the three watches, although Watch 1 was associated with the smallest number. This may be a function of inmates being in their cells asleep for at least some of the time during that watch.

Table C-2. Incidents across the Shifts

Shift	Percentage
Watch 1 (10 pm – 6 am)	24.7%
Watch 2 (6 am – 2 pm)	34.9%
Watch 3 (2 pm – 10 pm)	40.4%

Table C-3 presents incidents as a function of the general and specific locations where they occurred. Overwhelmingly, the incident report data reveal that areas where inmates are housed (e.g. cells, dorms) contained the most incidents.

Table C-3. Areas in Which Incidents Occurred

General Location	Specific Location	Percentage
Administration Area	Administration Area	00.7%
	Captain Office	00.7%
	Sergeant Office	00.8%
Chow Hall	Chow Hall	02.5%
Control Booth	Control Booth	00.4%
Court	Court	00.4%
Gate	Gate	00.4%
Entrance Gate	Entrance Gate	00.4%
Gym	Gym	01.1%
Housing	Bathroom	01.5%
	Cell	30.2%
	Dayroom	08.0%
	Dorms	12.7%
	Hallway	02.2%
	Showers	02.2%
	Undetermined housing	04.4%
	Upper Tier	00.7%
Kitchen	Kitchen	00.7%
Visiting Area	Visiting Area	00.7%
Laundry/Vocational	Classroom	03.3%
	Education Building	00.4%
Medical	Hospital	00.4%
	Infirmary	00.7%
	Medication Window	00.4%
	Nurse Station	00.4%
Parking Lot	Parking Lot	01.1%
Program Office	Program Office	01.8%
Receiving & Releasing	Receiving & Releasing	04.0%
Sally Port	Sally Port	00.4%
Telephone Area	Telephone Area	00.4%
Yard	Yard	07.6%
Other	Undetermined	08.4%

Table C-4 shows the percentage of the incidents where vision, hearing, or both vision and hearing informed Correctional Officers that an incident was occurring. It is not surprising that vision plays such a large role in this context given that (a) prison environments are relatively noisy and will thus make it difficult to hear soft sounds or voices, and (b) some incidents may be occurring at a considerable distance from Correctional Officers (e.g., across the yard) forcing Correctional Officers to rely more on vision than hearing.

Nonetheless, more than a quarter of the cues for detecting incidents were exclusively based on hearing, and another 23% involved hearing as a critical component. These results make it clear that hearing is a very important sensory ability for Correctional Officers.

Table C-4 Sensory Cues for the Incidents

Sensory Cue	Percentage
Vision only	48.4%
Hearing only	28.7%
Both vision and hearing	22.9%

Cross Tabulations of Time for Incident Report Analysis

Even when an incident is detected by using hearing only, vision only, or using a combination of vision and hearing, a good deal of the activities in which Correctional Officers engage during incidents do in fact involve the ability to hear. Correctional Officers very often need to communicate with inmates who are experiencing medical problems or who are acting in an oppositional manner, and they will almost always need to communicate with other Correctional Officers who are either involved in or who have responded to an incident.

The two cross tabulations reported here are limited exclusively to incidents associated with hearing only as the cue that informed the Correctional Officers an incident was occurring. These analyses thus focus on the hearing-critical function of detecting an incident (and not on the hearing functions during incidents).

Watch was cross tabulated with incident location and then with incident category. Because two large categories were cross tabulated, and because the analysis was limited to hearing only cues, the raw frequencies are small. The limited amount of data calls for caution to be used in drawing anything other than possible trends from these results.

Table C-5 contains summaries of the cross tabulations for hearing based incidents by location. The majority of incidents occurred in housing areas, specifically cells and dorms. In cells, most of the incidents occurred during the first and third watch. The second watch most likely had fewer incidents because the inmates are in other facility locations (e.g., yard, dayroom, chow hall, vocation) during this time period. Dorms also contain a large portion of hearing-based incidents. For dorms, there was a fairly even spread of incidents across the three watches, with a slightly higher rate of incidents occurring during the second watch. Because dorms house inmates within a single and relatively large living space, it is reasonable to assume that incidents could occur around the clock since there is a better chance of inmates being around each other (as opposed to being in separate cells).

Table C-5 Incident Location by Watch

Location of Incident	Watch					
	Watch 1	**%**	**Watch 2**	**%**	**Watch 3**	**%**
Housing						
Cell	10	37.0%	4	14.8%	13	48.1%
Dorms	3	25.0%	5	41.7%	4	33.3%
Undetermined	2	50.0%	1	25.0%	1	25.0%
Shower Area	0	0.0%	0	0.0%	2	100%
Dayroom	0	0.0%	2	50.0%	2	50.0%
Upper Tier	0	0.0%	1	100%	0	00.0%
Hallway	0	0.0%	2	33.3%	1	66.7%
Yard	0	0.0%	3	75.0%	1	25.0%
Medical						
Nurses' Station	0	0.0%	1	100%	0	00.0%
Hospital	1	100%	0	0.0%	0	00.0%
Receiving and Releasing	2	50.0%	2	50.0%	0	00.0%
Kitchen	0	0.0%	3	100%	0	00.0%
Other	0	0.0%	2	100%	0	00.0%
Program Office	0	0.0%	1	100%	0	00.0%
Undetermined Area	1	20.0%	3	60.0%	1	20.0%
Administration Area	0	0.0%	0	0.0%	1	100%
Telephone Area	0	0.0%	1	100%	0	00.0%
Captain's Office	0	0.0%	1	100%	0	00.0%
Sergeant's Office	0	0.0%	1	100%	0	00.0%
Entrance Gate	0	0.0%	1	100%	0	00.0%

Table C-6 presents the cross tabulations for hearing-based incidents by incident category. For incident categories, oppositional behavior, medical intervention, and one-on-one physical assaults were all frequent hearing incidents. For oppositional behavior, there was an even spread of incidents across all watches. For medical intervention, most of the incidents occurred during the third and first watch. For one-on-one physical assaults, most of the incidents occurred during the second and third watch. For medical intervention, most of the incidents occurred during the third and first watch.

Table C-6. Incident Category by Watch

Category of Incident	**Watch**					
	Watch 1	**%**	**Watch 2**	**%**	**Watch 3**	**%**
Contraband	5	100%	0	0.0%	0	0.0%
Medical Intervention	3	33.3%	1	11.1%	5	55.6%
Physical Assault one-on-one	1	9.0%	5	45.5%	5	45.5%
Physical Assault 3+ people	1	33.3%	1	33.3%	1	33.3%
Oppositional Behavior	7	26.9%	8	30.8%	11	42.3%
Unusual Behavior	0	0.0%	1	50.0%	1	50.0%
Suicide, Suicide Attempt/Threat	1	25.0%	3	75.0%	0	0.0%
Miscellaneous	1	5.9%	14	82.4%	2	11.8%
Multiple Elements	0	0.0%	1	50.0%	1	50.0%

Appendix D: Questions used in interviews

Each hearing-critical job function identified by the Correctional Officer panels was examined using the following questions.

Question:

- Was the task speech or non-speech?

If speech:

- Was the voice level a whisper, normal, raised, or shouted level?
- How much of the message did you understand?
    - *Low*- Did not hear enough of the message to figure it out
    - *Medium*- Understood the general idea of the message, but missed most of the details
    - *High*- Understood most of the message
    - Could the message be repeated?

If not speech:

- What did you know about the sound?
- **Detection**- Heard something
    - *Low*- Uncertain (thought I heard something)
    - *Medium*- Moderately certain (heard something)
    - *High*- Certain (certain of what I heard)
- **Recognition**- Heard and knew what I heard
    - *Low*- Uncertain (thought I heard something)
    - *Medium*- Moderately certain (heard something)
    - *High*- Certain (certain of what I heard)

- **Location**- Knew where the sound came from
    - *Low*- Uncertain about the direction that the sound came from
    - *Medium*- Know the very general direction of where the sound came from
    - *High*- Know within a narrow margin the direction where the sound came from
- **Location and Recognition**- Heard and knew where the sound came from
- How loud was the sound? (Soft, Medium, or Loud)
- How frequent was the sound? (Single, Continuous, or Intermittent)

Questions for both speech and non-speech sounds:

- How far away (in feet) was the sound?
- Was the sound source visible?
- How loud was the background noise? (Quiet, Medium, or Loud)
- What was the accuracy required to hear? (Low, Medium, High)
- What was your overall effort to hear? (Low, Medium, or High)

Appendix E: Architectural designs for prison housing facilities

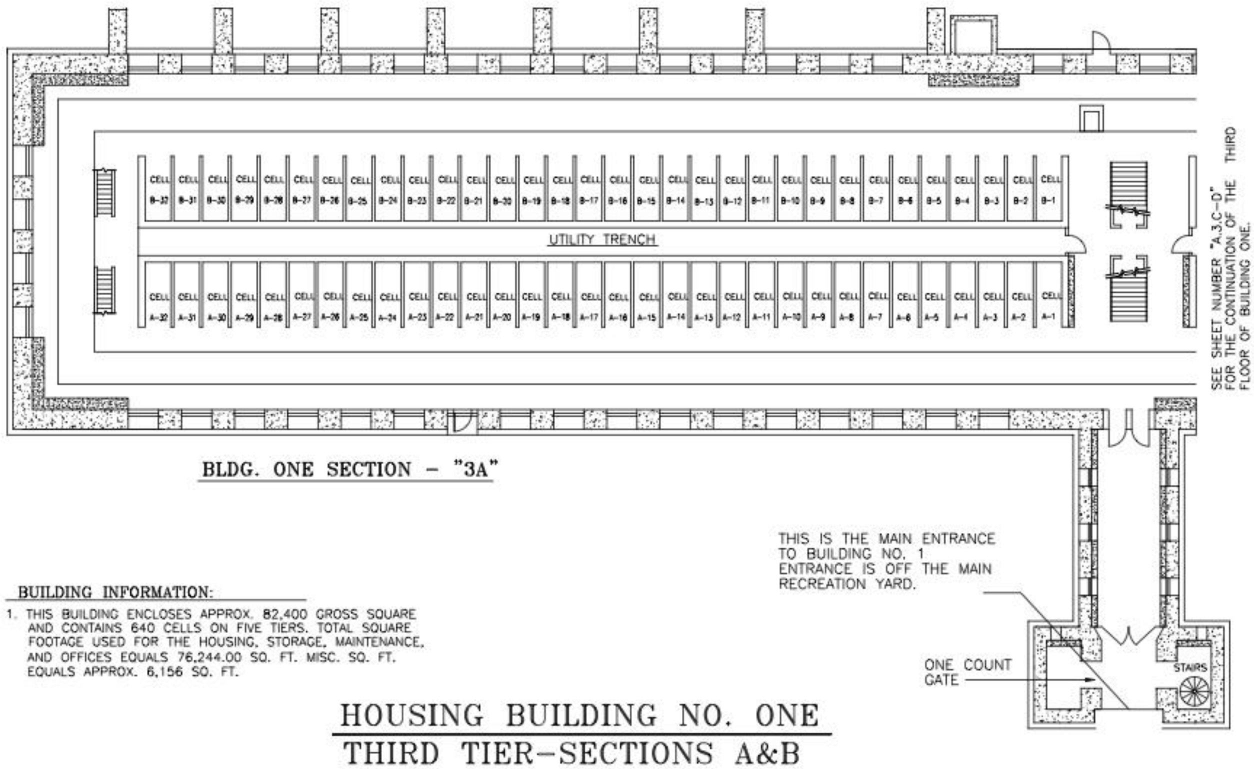
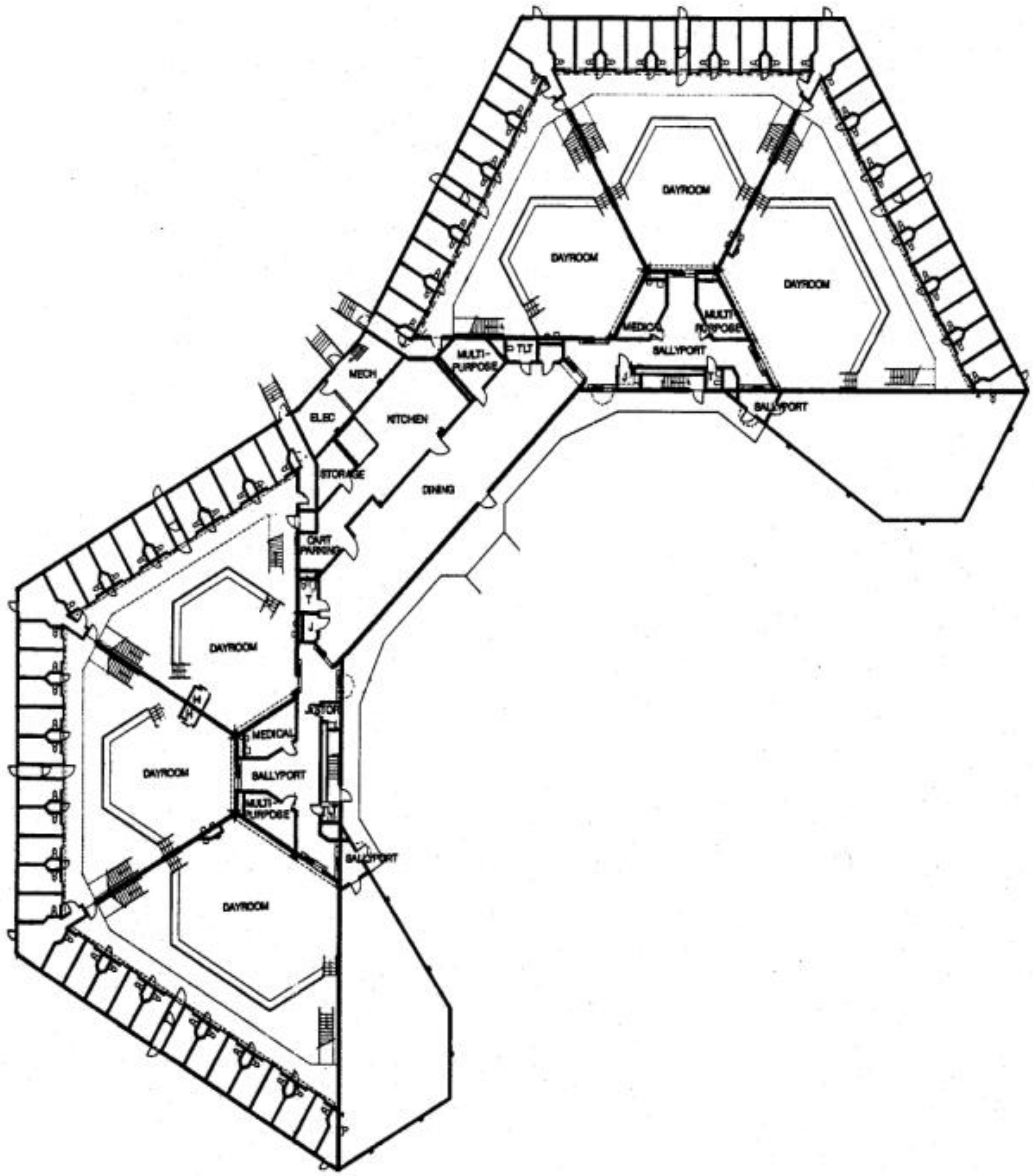


Figure E-1. Tiered housing design



180 HOUSING LOWER LEVEL PLAN

Figure E-2. Lower level of a 180 degree housing design.

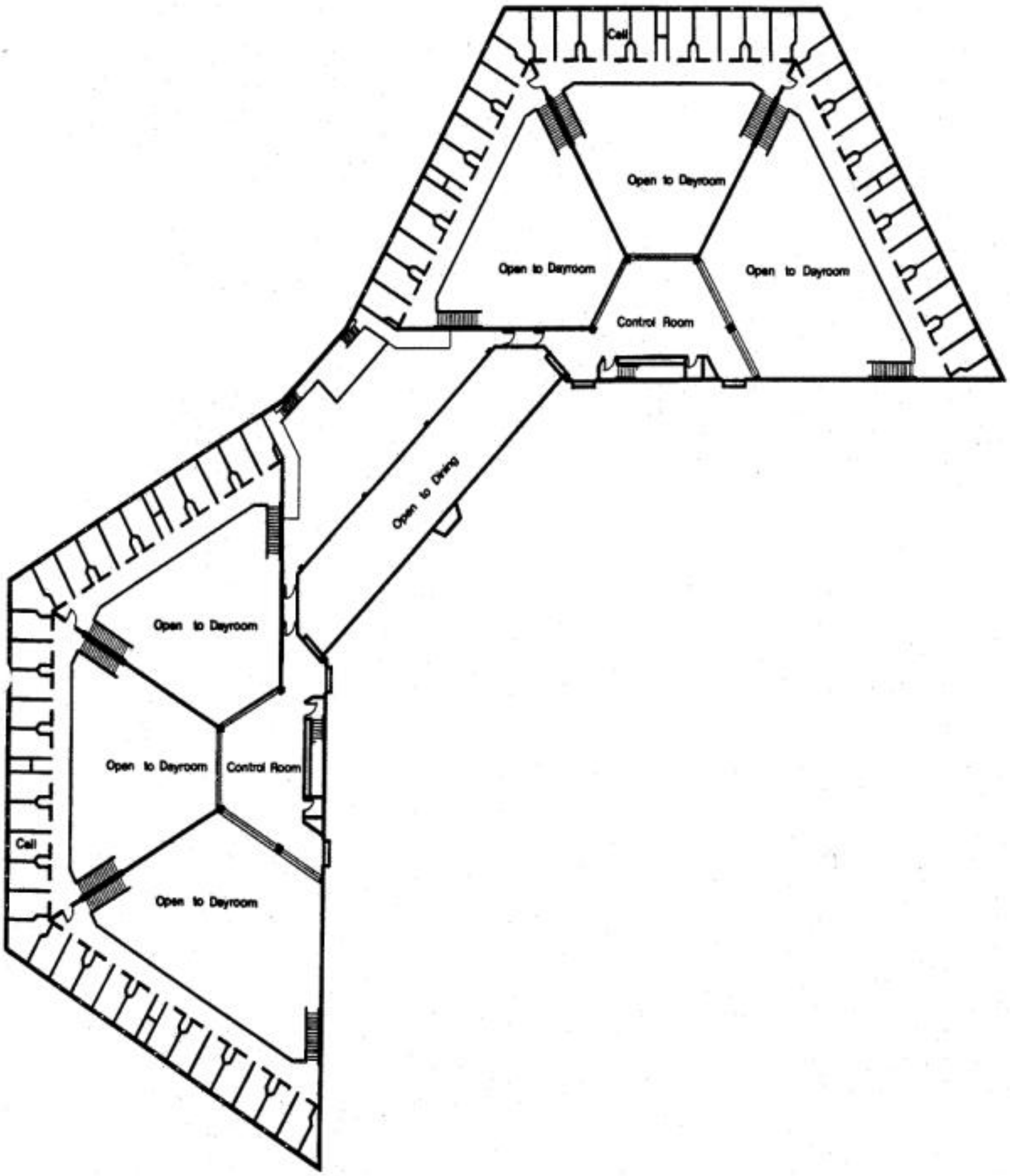
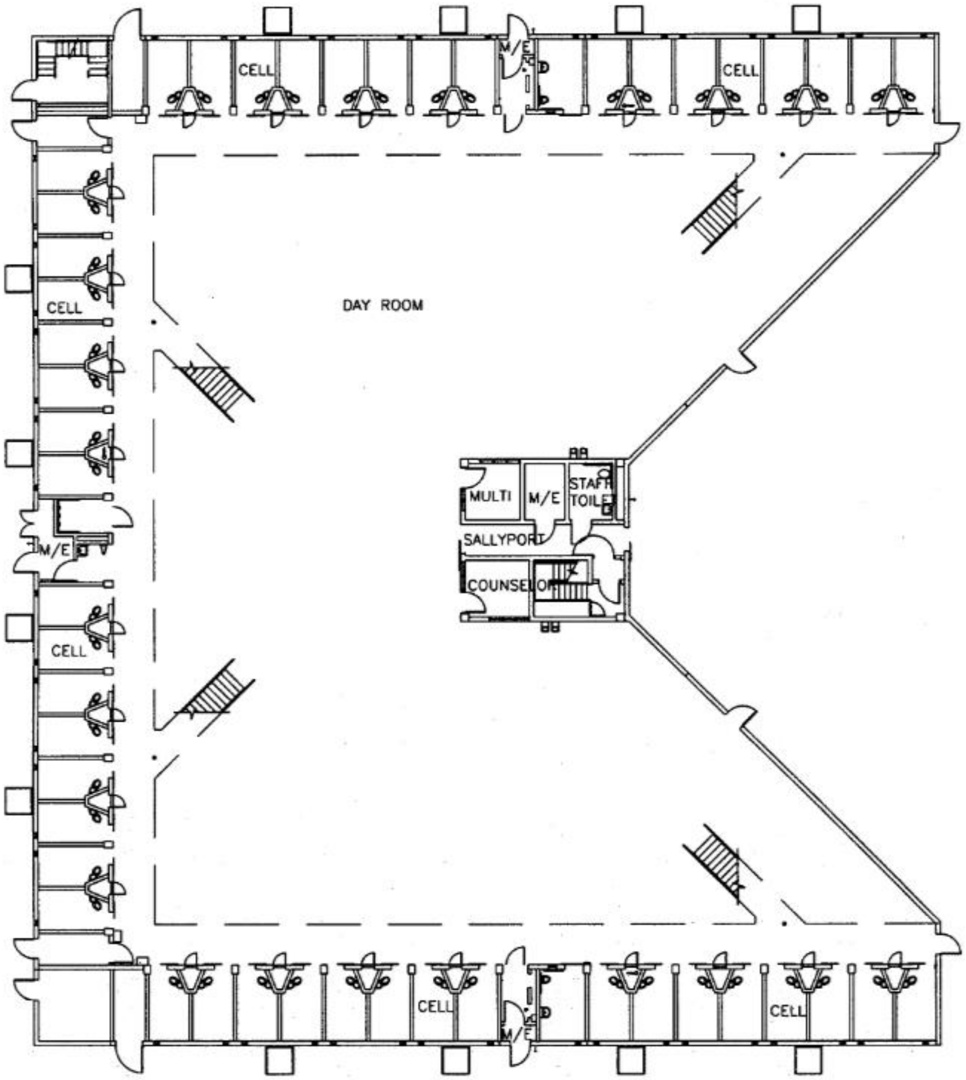
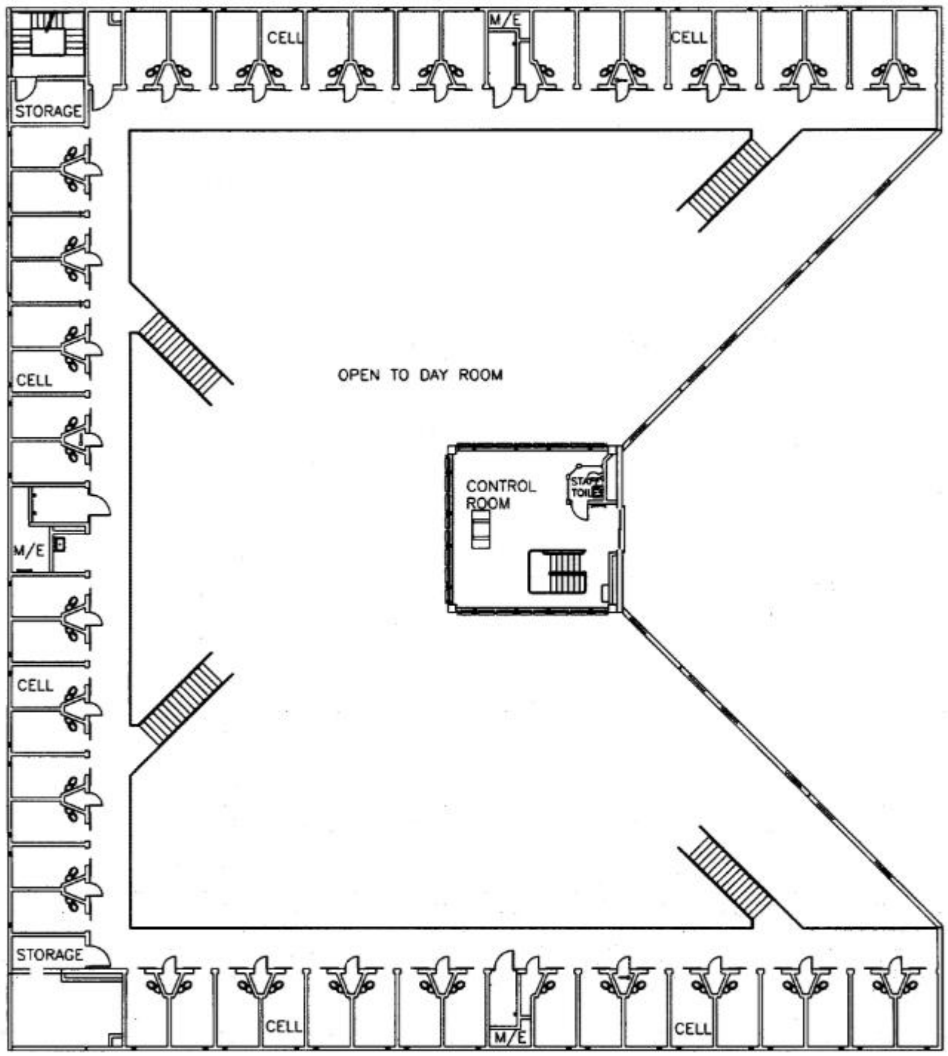


Figure E-3. Upper level of a 180 degree housing design.



270 HOUSING LOWER LEVEL PLAN

Figure E-4. Lower level of a 270 degree housing design.



270 HOUSING UPPER LEVEL PLAN

Figure E-5. Upper level of a 270 degree housing design.

Appendix F: Description of sampled prisons

Northern California Facilities

Mule Creek State Prison: Located in Ione, this facility covers 866 acres. It was opened in 1987. Mule Creek State Prison houses inmates with Security Levels I, II, III, and IV. The facility is primarily a 270 design, but also has dormitories and single cells. Currently, Mule Creek State Prison houses approximately 3,800 inmates and employs 600 custody staff.

Folsom State Prison: Located in Folsom, this facility covers 40 acres. Opened in 1880 it is the second oldest state prison (San Quentin is the oldest). Folsom State Prison is primarily a Level III facility but also houses Level I and Level II inmates. The facility is primarily a multi-tiered (5 floors) design facility, but also has dormitories and single cell housing units. It houses approximately 4,400 inmates and employs 660 custody staff.

California State Prison Sacramento: Also located in Folsom, this facility covers 1200 acres. It was opened in 1986. The facility houses maximum security inmates serving long sentences or those that have proven to be management problems at other institutions, as well as inmates with Security Levels I, II, and IV. The institution also serves as a medical hub for Northern California prisons including Psychiatric Services Unit. The institution currently has an Outpatient Housing Unit and a Correctional Treatment Center. California State Prison Sacramento houses approximately 3,200 inmates and employs 1016 custody staff.

Central California Facilities

Valley State Prison for Women: Located in Chowchilla, this facility covers approximately 640 acres. It was opened in 1995. Valley State Prison functions as a Reception Center and houses Levels I, II, III, and IV inmates. The facility design is primarily dormitories; however, it also has multi-person cells, and single cells. The prison has grown to be one of the largest women's prisons in the world, now housing approximately 3,700 inmates and employing 500 custody staff.

Salinas Valley State Prison: Located in Soledad this facility covers 300 acres. It was opened in 1996. It is designated to house Security Levels I, III, and IV inmates. The housing of these inmates is accomplished in two 270 design facilities and two 180 design facilities. Salinas Valley State Prison also has a 100-cell stand-alone unit. Salinas Valley State Prison also serves as an intermediate care inpatient psychiatric program servicing primarily Level IV high security inmates who have a major mental disorder that has diminished their ability to function within the prison environment. The prison houses approximately 450 inmates and employs 870 custody staff.

Southern California Facilities

California Correctional Institution: Located in Tehachapi, this institution covers 1,650 acres. It was opened in 1933 but has had several architectural modifications since that time. It houses inmates with Security Levels I, II, and III, and also functions as a Reception Center. This institution has buildings with a 270 and 180 design; it also has dorms and single cell housing units. The California Correctional Institution contains most of the design features except for the multi-tiered design. It houses approximately 5,700 inmates and employs 1,100 Correctional Officer custody staff.

North Kern Valley State Prison: Located in Delano, this facility covers 640 acres. It opened in 1993. The facility houses general population inmates who are typically classified as Security Levels I and II. The facility is primarily a 270 design, but it also has dormitories, multi-persons cells, and single cell housing units. The prison also functions as a reception center for the processing of incoming inmates from southern and some northern counties, and is also the transportation hub for the central facilities. North Kern Valley State Prison houses approximately 5,300 inmates and employs 1,000 custody staff.

Appendix G: Methodology for making on-site calibrated sound recordings

All recordings were made using a hand-held digital audio recorder, the Edirol R-09HR manufactured by Roland. Recordings were made in stereo using the built in microphones on the device. The sampling rate was set to 44.1 kHz, and the sampling word length was set to 24 bits. According to the manufacturer's specifications, the microphones exhibit a uniform polar plot with directional variations in sensitivity of less than 3 dB. The manufacturer's specification also state that the microphone's frequency response is flat from 50 Hz up to 8 kHz, although this did not prove to be the case during calibration measurements. Recordings were stored on an SD memory card and later transferred to a personal computer for processing and analysis.

The field recordings from each location at each facility were manually edited to remove spoken comments by the individuals making the recordings and comments by Correctional Officers and other prison staff. A free waveform editing software tool, Audacity (Version 1.2.6), was used to excise comments from each recording, leaving only the background noise for subsequent analysis. The remaining background noise often consisted of the voices of staff and inmates in addition to the sounds of equipment and other sounds typically present in those environments.

Appendix H: Calibration procedures

Calibration of the recorder was done with the microphone sensitivity set to “high” and input gain set to “40,” which is midrange on a scale with a maximum setting of 80. Automatic gain control and compression features of the recorder were turned off at all times (the Edirol R-09HR is designed for recording live music, and thus is capable of sampling high sound pressure levels over a wide dynamic range). Calibration was performed using a Fonix 7000 Hearing Aid Analyzer manufactured by Frye Electronics. The recorder was turned on and placed in the Fonix test box. A 1 kHz pure tone was presented at 80 dB SPL and recorded for approximately 2 minutes. This recording was transferred to computer via the SD memory card, and its root mean square (RMS) level was calculated using Matlab. The RMS level expressed in dB corresponds to 80 dB SPL and to 80 dB (A), since dB SPL and dB (A) are equivalent at 1 kHz.

A second set of calibration recordings at different frequencies was made using the same procedure described above. Pure tones at 80 dB SPL were presented at 100 Hz intervals ranging from 100-1000 Hz and at 1000 Hz intervals ranging from 1000-8000 Hz (these are the intervals and frequencies that the Fonix system is capable of producing). The RMS values for these recordings revealed that the microphone frequency response was flat up to about 2 kHz, and then decreased by about 6 dB per octave up to 8 kHz.

The frequency-specific calibration recordings were used in two different ways. First, they provided the information necessary to convert RMS values to dB SPL for each of the 18 1/3 octave band filter outputs used to calculate SII and ESII. A total of 9 of the 18 center frequencies for these filters correspond to calibration frequencies measured with the Fonix system, with the lowest being 200 Hz and the highest 8000 Hz. Calibrations for the remaining 9 filter outputs were obtained by extrapolation.

The second use of the frequency-specific calibration recordings was to specify the frequency response for a modified A-weighted filter that could be used both to apply A-weighting and pre-emphasis to the recordings so that accurate L(eq) values could be calculated for each recording. L(eq) is expressed in dB (A) and is the long term RMS of the recording after A-weighted filtering. Use of a standard A-weighted filter to obtain the L(eq) for the current recordings would underestimate the true L(eq) because of the roll off in the frequency response of the microphone above 2 kHz. Thus, a modified A-weighted filter was designed with a frequency response matching the specifications for A-weighting up to 2 kHz. Above this frequency, 6 dB per octave of pre-emphasis was added to the specifications for A-weighting. Application of this pre-emphasis gain did not cause saturation in any of the recordings.

Appendix I: Detailed summary of sound recordings

A total of 87 recordings were made at the specified locations from the 7 facilities. Four of these recordings were not useable, leaving a total of 83 recordings for analysis. The details describing these recordings are presented Table I-1. The recordings are organized according to location within the facilities. The date and time of the recording and the facility where the recording was made are given in the left columns of the table. The column labeled "Sample" is used to indicate whether the recording was included in the ESII data set for the location. Those that were included are indicated with an "X." The objective in selecting recordings for inclusion in the ESII data set for a location was to obtain up to 5 recordings without using more than one recording from the same location. However, this was not possible for all locations. Note that only one recording was obtained from linear housing and three recordings from the same facility (Folsom State Prison) were obtained from tiered housing. These two types of housing design are uncommon, and thus limited in availability.

The table also describes the general area where the recording was made (e.g., "control booth") and the specific location of the recording within the general area. The activity in progress at the time of the recording is also given. This information was noted on a recording log that was completed at the time of the recording. Note that for a few of the recordings (numbers 1, 5, and 9) incomplete information is reported. These recordings were made by the Correctional Officer escort in areas where the recording team was not allowed to enter because of security concerns.

The table also summarizes the research team's assessment of the characteristics of the noise, including its source, the distance of the source from the recording, and an estimate of the noise level. Also recorded was an estimate of the vocal effort used for speech communication by the Correctional Officers. Raised or loud vocal effort was used for communication almost twice as often as normal vocal effort. The most common noise sources were the voices of the staff and inmates and the sounds associated with their activities. Exceptions to this general observation were seen for recordings from the kitchen, laundry, and vocational areas; in these areas, equipment was also a common noise source. The distance of the noise from the recorder varied widely because in most cases there were multiple noise sources. The log keeper most often judged the level of the noise to be "loud."

It should be noted that the presence of the research team members with clipboards and recording instruments often had the effect of drawing the inmates' attention and, in so doing, quieting their vocal activities. A number of the Correctional Officer escorts observed that this was happening. Thus, the typical noise levels may actually be higher than those observed on some of the recordings.

The remaining entries in the table were generated at the time the recordings were processed. The duration of the original untrimmed recording is reported, as well as the percent of the recording that contained spoken communication between the recording team and the Correctional Officers. Intervals containing communication exchanges were excised from the recording before the analyses were performed. The L(eq) for each trimmed recording is also reported. The L(eq) for each trimmed recording was calculated as the long term RMS of the recording after it had been filtered with the modified A-weighting filter. L(eq) values were typically between 70 and 85 dB (A). In kitchen and vocational locations the L(eq) often exceeded 85 dB (A).

Finally, the number of ESII values calculated for each recording is given, together with the percent of those values that were used in the pooled analysis for the location. Recall that ESII values for 30 4-second samples uniformly distributed throughout the recording were used for the pooled analysis.

Table I-1. Summary Description of All Recordings

Nr	Date	Time	Facility	Sample	General area	Recorder location	Activity	Noise characteristics: Souce	Noise characteristics: Distance	Noise characteristics: Level	Vocal effort	Recording duration (min): Untrimmed	Recording duration (min): Percent	L(eq)	ESII samples	Percent analyzed
								Control Booth								
1	11/16/09	12:30 PM	CCI	X	Control booth	educational release						5.98	9.7%	**76.19**	35,149	37.1%
2	11/12/09	12:42 PM	CSP	X	Control booth 5	center, window	release to yard	inmate voices leaving cells	1-20	M	R	8.48	10.8%	**74.86**	49,215	26.5%
3	11/18/09	10:11 AM	Kern	X	CTC	officer desk area	answering phones	keys, voices, doors	5-10	L-M	N	5.05	4.0%	**77.69**	45,032	29.0%
4	11/23/09	12:07 PM	Mule Creek	X	Control booth, 270	center of booth	supervise door, monitor phones	voices, typewriter	20-50	L	N	5.30	77.4%	**67.44**	15,754	82.8%
5	1/11/10	1:03 PM	SVSP	X	Control booth	with CO	yard release					14.50	10.0%	**62.12**	32,347	40.3%
6	11/16/09	9:45 AM	CCI		Control booth	inside booth, rear area	give out keys, open doors, phone	voices	5-10	L	N	5.02	13.6%	**78.71**		
7	11/12/09	12:57 PM	CSP		Control booth 7	look to cells	inmates in cells	voices	1-20	L	L	4.13	25.8%	**73.28**		
8	11/18/09	9:56 AM	Kern		Central control	middle of room	phones, radio, gates	voices, rings, alarms	5-10	L-M	N	5.00	10.7%	**72.23**		
								Chow Hall								
9	11/16/09	12:49 PM	CCI	X	Dining hall	yard release						4.33	1.5%	**79.52**	27,774	47.0%
10	2/5/10	5:26 PM	Folsom	X	Bldg 1 chow hall	near tray return	Feeding inmates	trays, voices, keys, kitchen equipment	5-100	L	R-S	2.02	0.0%	**79.10**	28,983	45.0%
11	11/18/09	5:59 PM	Kern	X	Dining hall	walk around with CO	seating and eating	voices of ~100 inmates	5-40	H	R-S	5.07	11.2%	**75.44**	29,272	44.6%
12	1/11/10	4:06 PM	SVSP	X	Dining hall 1	walk around edge	feeding inmates	inmate voices, cafeteria noise	5-100	L	R	6.03	12.7%	**76.12**	34,327	38.0%
13	12/21/09	5:31 PM	VSP	X	Dining area	in dining hall	dinner	100+ inmates eating, trays	5-30	L	R	5.08	8.2%	**81.82**	30,372	43.0%
14	2/5/10	5:13 PM	Folsom		Bldg 1 chow hall	walking around	feeding inmates	trays, voices, keys, kitchen equipment	5-100	L	R-S	3.01	0.0%	**78.39**		
15	2/5/10	5:48 PM	Folsom		Unit 5	chow hall	feeding inmates	trays, voices, keys, kitchen equipment	5-100	L	R-S	5.07	15.8%	**82.96**		
16	1/11/10	4:20 PM	SVSP		Dining hall 2	walk around edge	feeding inmates	inmate voices, cafeteria noise	5-100	L	R	6.02	3.0%	**78.04**		

Table I-1 (continued)

`	Date	Time	Facility	Sample	General area	Recorder location	Activity	Noise characteristics: Souce	Noise characteristics: Distance	Noise characteristics: Level	Vocal effort	Recording duration (min): Untrimmed	Recording duration (min): Percent	L(eq)	ESII samples	Percent analyzed
Housing: 270/180 Design																
17	11/19/09	9:54 AM	Kern	X	270 A housing	control booth	monitor dayroom and yard	voices, radio, phone	10-40	N	R	5.17	7.7%	**69.71**	31,078	42.0%
18	11/23/09	11:56 AM	Mule Creek	X	Bldg 14 C, housing	officer's area	count, radio, intercom	voices, radio, doors	5-30	M	N-S	5.82	35.8%	**74.81**	15,754	82.8%
19	1/11/10	12:34 PM	SVSP	X	Delta 4 EOP (2)	walking around	EOP housing	voices, keys, phones, doors	5-30	N	N	3.05	25.1%	79	14,933	87.4%
20	12/21/09	4:51 PM	VSP	X	Ad Seg housing	middle of dayroom	cell feeding	voices, keys, carts, port closing	5-30	L	L	3.37	3.0%	**72.07**	21,311	61.2%
21	11/19/09	9:50 AM	Kern		270 A housing	officer area	dayroom	voices	5-30	L	N	2.10	38.9%	**69.58**		
22	1/11/10	12:32 PM	SVSP		Delta 4 EOP	walking around	EOP housing	voices, keys, phones, doors	5-30	N	N	1.18	26.8%	**77.20**		
23	12/21/09	4:47 PM	VSP		Ad Seg housing	middle of dayroom	cell feeding	inmate voices, keys	5-30	L	L	2.83	44.1%	**69.42**		
Housing: Dorm Design																
24	11/16/09	10:32 AM	CCI	X	Gym/dorm	rear control area	TV, sleeping, showering	122 inmates	5-30	M	N	5.13	4.5%	**82.44**	31,895	40.9%
25	11/18/09	10:45 AM	Kern	X	Dorm 6	middle rear officer station	TV, voices, shower, intercom	TV, voices, Showers	5-30	M	R	3.02	18.8%	**72.37**	16,004	81.5%
26	11/18/09	11:55 AM	Kern	X	Dorm C2	rear by officer station	phone, shower, radio, intercom, TV	TV, voices, Showers	5-30	L	R	6.17	64.9%	**84.13**	19,548	66.8%
27	11/18/09	12:04 PM	Kern	X	Dorm 1	rear by officer station	phone, shower, laundry, talk	TV, voices, Showers, phone, intercom	5-60	H	R-S	5.32	11.3%	**78.88**	30,708	42.5%
28	11/16/09	10:37 AM	CCI		Gym/dorm	walk through gym	TV, sleeping, showering	122 inmates	5-30	M	N	1.72	44.7%	**81.14**		
29	11/12/09	1:22 PM	CSP		Gym/dorm	officer area	RV, inmates walking talking	3 TV, voices	10-100	H	R	5.05	29.7%	**81.26**		
30	11/18/09	10:38 AM	Kern		Dorm L2	rear of dorm	showers, TV, talk	showers, TV, voices	5-10	L	N	2.68	62.7%	**77.68**		

Table I-1 (continued).

Nr	Date	Time	Facility	Sample	General area	Recorder location	Activity	Noise characteristics: Souce	Noise characteristics: Distance	Noise characteristics: Level	Vocal effort	Recording duration (min): Untrimmed	Recording duration (min): Percent	L(eq)	ESII samples	Percent analyzed
								Housing: Linear Design								
31	12/21/09	10:31 AM	VSP	X	Dayroom	TV room, guard station	phone calls, view TV, talk	voices, TV, PA, keys	5-30	M	N	3.48	47.8%	**70.05**	23,716	55.0%
								Housing: Tiered Design								
32	1/13/10	10:40 AM	Folsom	X	Unit 1, tiers	officers station	Inmates in/out of cells	voices, radio, keys, bars	5-150	L	R-S	5.07	20.7%	**81.66**	26,294	49.6%
33	1/13/10	10:49 AM	Folsom	X	Unit 5, tiers	officers station	Inmates in/out, showers, barber	shower, voices, keys, radio	5-150	L	R-S	5.06	52.0%	**78.74**	17,729	73.6%
34	1/13/10	10:58 AM	Folsom	X	Unit 2, tiers	officers station	Inmates in/out, showers	shower, voices, keys, radio	5-150	L	R-S	5.19	20.8%	**80.15**	27,240	47.9%
35	2/5/10	5:36 PM	Folsom		Unit 5	officers station	chow release	voices	5-100	N	N	2.36	0.0%	**73.40**		
								Kitchen								
36	11/18/09	4:55 PM	Kern	X	Re-therm	walk around	washing dishes	pots and pans, voices	5-60	H	R-S	5.38	25.4%	**85.20**	18,829	69.3%
37	11/23/09	9:30 AM	Mule Creek	X	Central kitchen	walk around	washing, baking, cooking	pots and pans, water, voices, radio	5-40	L	R-S	5.50	49.4%	**87.63**	18,147	71.9%
42	1/11/10	3:36 PM	SVSP		Food prep area	walking around	food prep, serve chow	voices, trays, water, fans, keys	5-100	L	L	8.02	25.6%	**82.58**	28,028	46.6%
39	12/21/09	9:44 AM	VSP	X	Central kitchen	cooking area	cleaning pots & pans, cooking	water, pots and pans, voices, keys, doors	5-30	L	R	2.95	21.5%	**89.16**	15,066	86.6%
40	11/17/09	8:17 AM	CCI	X	Central kitchen	walking around	sweeping, baking, mopping	machines, p&p, voices	5-10	L	R	5.18	13.2%	**73.77**	29,290	44.6%
41	11/18/09	5:00 PM	Kern		Re-therm	walk around with CO	washing dishes	pots and pans, voices	5-40	H	R-S	3.12	7.5%	**87.99**		
38	1/11/10	10:31 AM	SVSP	X	Central kitchen	walking around	cooking, washing	carts, trays, dishes, radio, keys	5-30	L	L	5.18	17.0%	**86.03**		
43	12/21/09	9:48 AM	VSP		Central kitchen	cooking area	cleaning pots & pans, cooking	steam, voices, pots and pans	5-30	L	R	4.87	30.8%	**89.66**		
44	12/21/09	11:02 AM	VSP		Central kitchen	near workers	cooking, packing lunches	voices, pots and pans, dishes, running water	5-30	L	R	5.02	11.6%	**86.02**		
45	12/21/09	5:02 PM	VSP		Satellite kitchen	walk around area	reheat food	voices, pots and pans, dishes, running water	5-30	L	R	3.03	28.0%	**84.73**		

Table I-1 (continued).

Nr	Date	Time	Facility	Sample	General area	Recorder location	Activity	Noise characteristics Souce	Distance	Level	Vocal effort	Recording duration (min) Untrimmed	Percent	L(eq)	ESII samples	Percent analyzed
								Laundry								
46	11/12/09	1:34 PM	CSP	X	Laundry	walking around	laundry machines	machines	10-30	H	R	5.42	22.5%	**85.57**	27,376	47.7%
47	12/22/09	8:45 AM	VSP	X	Central laundry	walking around	washing, drying, moving carts	voices, machines, carts	5-30	M	R	5.02	32.2%	**80.93**	22,183	58.8%
48	11/16/09	9:58 AM	CCI		Central laundry	walk around	run washing machines	washers, dryers	5-10	H	R	2.25	25.2%	**80.55**		
49	11/16/09	10:00 AM	CCI		Clothing room	walk around	fold clothes, issue shoes	voices	5-10	L	N	3.02	3.3%	**61.96**		
								Medical								
50	11/16/09	10:21 AM	CCI	X	Medical clinic	holding area	medical movements	voices, doors	5-10	M	N	5.03	10.6%	**75.36**	29,300	44.5%
51	11/18/09	10:18 AM	Kern	X	Diagnostic corridor	middle of room	waiting area for inmates	voices, keys, radios	5-10	M	R	4.07	23.4%	**71.24**	20,327	64.2%
52	11/24/09	10:56 AM	Mule Creek	X	TTA alarm	officer's area	alarm	AC, radio, boiler, voices	20-40	M-L	R-S	1.20	18.1%	**82.44**	19,254	67.8%
53	1/11/10	10:08 AM	SVSP	X	Medical	center of officer station	Medical appointments	voices, keys, phones, doors	5-20	N	N	5.07	0.0%	**69.77**	30,201	43.2%
54	12/22/09	8:56 AM	VSP	X	Medical facility	officer station	medical services, conversation	voices, keys	5-30	L	R	5.03	17.9%	**64.98**	26,928	48.5%
55	11/24/09	10:39 AM	Mule Creek		Treatment triage area	officer's area	process inmates for medical	voices, keys, doors, chains	20-40	M	R-S	15.80	31.5%	**82.28**		
56	1/11/10	11:09 AM	SVSP		Central hospital	officer area	inmate in/out movements	voices, keys, phones, doors	5-30	N	N	5.58	2.1%	**68.92**		
57	1/12/10	8:33 AM	SVSP		DMH medical	officer station	Prep for group counseling	voices, keys, phones, doors	5-60	N	N	5.07	8.6%	**70.66**		

Table I-1 (continued).

								Noise characteristics			Vocal	Recording duration (min)			ESII	Percent
Nr	Date	Time	Facility	Sample	General area	Recorder location	Activity	Souce	Distance	Level	effort	Untrimmed	Percent	L(eq)	samples	analyzed
								Receive & Release								
58	11/17/09	10:15 AM	CCI	X	R&R	middle of officer area	outprocessing	voices, chains, handcuffs, doors	5-10	L	N	10.85	1.2%	**75.58**	32,385	40.3%
59	11/17/09	10:53 AM	CCI	X	R&R	middle of officer area	inprocessing, inmate movement	voices, chains, handcuffs, doors	5-10	L	N	12.80	8.1%	**72.33**	32,967	39.6%
60	11/18/09	10:26 AM	Kern	X	R&R	officer's station	intake	voices, radios, carts, phones	5-10	M	R	7.20	3.9%	**75.29**	32,560	40.1%
61	11/19/09	9:23 AM	Kern	X	R&R	middle of officer area	LA intake	voices, toilet, keys, radio, doors	5-30	L	N	10.33	1.3%	**87.53**	44,210	29.5%
62	12/22/09	8:33 AM	VSP	X	R&R	officer station	receiving inmates	doors, typewriter, voices, keys	5-30	M	R	5.00	1.7%	**74.50**	32,017	40.8%
63	11/17/09	10:37 AM	CCI		R&R	middle of officer area	inprocessing, inmates enter	voices, chains, handcuffs, doors	5-10	L	N	4.62	5.4%	**68.76**		
64	11/19/09	9:08 AM	Kern		R&R	middle of officer area	intake	voices, toilet, keys, radio	5-30	M-L	R	7.68	11.5%	**85.77**		
								Vocational								
65	1/13/10	9:22 AM	Folsom	X	Paint shop	Walking around shop	Air hammer, other equipment	fan, heater, radio, dryers	5-100	L	R-S	5.00	18.8%	**88.42**	26,733	48.8%
66	1/13/10	9:31 AM	Folsom	X	License plate shop	Walking around shop	Machines, metal stamping, radio	same	5-100	L	R-S	5.04	32.5%	**88.76**	23,851	54.7%
67	12/21/09	10:48 AM	VSP	X	Optical shop	Walking around shop	grinding glass for eyewear	voices, grinders	5-30	L	N	4.68	50.5%	**80.05**	15,063	86.6%
68	1/13/10	9:17 AM	Folsom		Metal fab bldg	Walking around shop	Metal fab	equipment, fans, voices, grinders, radio	5-100	L	R-S	4.22	0.0%	**86.75**		
69	1/13/10	9:38 AM	Folsom		Print shop	Walking around shop	Packaging forms	voices, radio, presses	5-100	L	R-S	4.01	22.9%	**86.08**		
70	1/13/10	9:42 AM	Folsom		Metal sign shop	Walking around shop	Manufacturing signs	voices	5-100	L	R-S	4.11	19.2%	**75.83**		
71	1/13/10	10:16 AM	Folsom		Welding shop	Walking around shop	Vocational welding class	keys, radio, grinder, machines	5-60	L	R-S	5.03	12.3%	**88.78**		

Table I-1 (continued).

Nr	Date	Time	Facility	Sample	General area	Recorder location	Activity	Noise characteristics: Souce	Distance	Level	Vocal effort	Recording duration (min): Untrimmed	Percent	L(eq)	ESII samples	Percent analyzed
								Visitation								
72	2/6/10	10:39 AM	CSP	X	Visitor inprocessing	officer area	screening new visitors	voices, keys, phone, wand, baby crying	5-20	N	N	5.04	39.5%	**66.26**	20,098	64.9%
73	2/6/10	10:57 AM	CSP	X	Visitors area	officer desk	visiting inmates	voices, keys, phone, wand, baby crying	5-20	N	N	5.05	0.0%	**72.45**	33,048	39.5%
74	2/6/10	11:04 AM	CSP	X	Visitors area	walking around	visiting inmates	voices, keys, phone, wand, baby crying	5-20	N	N	2.32	2.3%	**75.75**	15,105	86.4%
75	2/6/10	11:41 AM	Folsom	X	Outside visiting area	walking around	visiting	voices, radio, PA system, baby crying	5-20	N-L	R	5.01	10.4%	**77.43**	27,562	47.3%
76	2/6/10	11:48 AM	Folsom	X	Inside visiting area	walking around	visiting	voices, radio, PA system, baby crying	5-20	L	R	6.01	15.0%	**79.53**	33,768	38.6%
								Yard								
77	11/17/09	8:50 AM	CCI	X	Yard	rear	individual exercise module	Ad Seg inmate voices raised	5-30	M	N	5.57	20.1%	**84.37**	28,963	45.1%
78	11/12/09	12:30 PM	CSP	X	Yard B	edge of exercise track	rec, inmates walking, talking	voices	50-100	L	N	6.88	49.4%	**72.91**	22,656	57.6%
79	1/13/10	10:33 AM	Folsom	X	Main yard	Walking around shop	Outside yard program	voices, keys, handball, carts	5-20	N	N-R	5.27	38.0%	**73.80**	22,505	58.0%
80	11/23/09	11:44 AM	Mule Creek	X	Yard C	walk around	rec, chapel, canteen	voices, keys	20-300	M	N-S	5.32	70.2%	**77.31**	20,728	63.0%
81	12/21/09	10:09 AM	VSP	X	A yard	Walking around in yard	rec time	voices, radio	5-30	M	N	4.62	44.8%	**71.86**	16,676	78.3%
82	11/17/09	8:44 AM	CCI		Upper patio	standing near fence	searching, several movements	doors, voices	5-30	L	N	5.23	29.3%	**74.33**		
83	11/12/09	1:06 PM	CSP		Yard	basketball	10-15 inmates playing b ball	game voices	5-20	M	R	2.93	14.2%	**75.78**		

Appendix J: Rationale for specification of critical value for the Extended Speech Intelligibility Index

To describe the process by which criterion ESII values are defined and applied, it is first necessary to consider the relationship between HINT SRTs, ESII, speech intelligibility, and the likelihood of effective speech communication in complex, fluctuating background noise environments. HINT SRTs were related to ESII (and SII) values by applying the 18 1/3-octave filter band analysis to the reference stationary HINT noise scaled to correspond to a sound pressure level of 65 dB(A), the presentation level used during testing. The filter outputs for the HINT noise were converted to spectrum levels and combined with the standard speech spectrum levels for normal vocal effort and the band importance function for "short passages of easy reading material" (ANSI S3.5-1997, 2007) to obtain the SII. Note that the standard also specifies 62.35 dB SPL as the standard speech spectrum level for normal vocal effort.

The SII for the HINT noise under these assumptions is 0.34. The HINT Noise Front condition most closely approximates the assumptions used for the SII calculation. The norm for individuals with normal speech communication ability in this condition is an SRT of 62.4 dB (A), closely approximating the standard speech spectrum level for normal vocal effort, and the SII at the Noise Front norm is 0.35. Thus, the ability of the SII to predict the Noise Front SRT for individuals with normal speech communication ability is evident. Note also that other investigators have found that the SII at the SRT to be approximately 0.34 (e.g., Houtgast & Festen, 2008).

The speech spectrum levels and band importance functions used to calculate the SII and ESII for the HINT Noise Front threshold are those reported in the standard short passages of easy reading materials produced with normal vocal effort (Tables 3 and B.2 in ANSI S3.5-1977, 2007). These speech spectrum levels from the standard for normal vocal effort (62.35 dB SPL at 1 meter) can be compared with the speech spectrum levels of the HINT sentences at the Noise Front threshold (62.4 dB(A) at 1 meter). The average spectrum level difference across the 18 1/3-octave bands was 0.98 dB, with the HINT speech spectrum levels slightly higher. More importantly the average spectrum level difference for the range of 1/3 octave bands from 315-3150 Hz, which contribute 82% of the overall band importance, was only 0.02 dB, with the spectrum levels in the standard slightly higher. These data indicate there are small differences in the HINT and ANSII spectrum levels at the extremes of the frequency range for the 1/3-octave band filters; however, the impact of these differences on the ESII calculations and the hearing screening standard is anticipated to be minimal because of the very close agreement in spectrum in the mid frequency regions where band importance is greatest for speech intelligibility.

Speech intelligibility, measured as the percent of words correctly recognized from all sentences, is approximately 70% at the HINT SRT for Noise Front and for the other HINT test conditions as well (Nilsson et al., 1994; Vermiglio, 2008). The slope of the function relating percent intelligibility to presentation level for levels near the SRT is 10%/dB (Soli & Wong, 2008). Thus, increasing the presentation level by 3 dB from 62.4 dB (A) to 65.4 dB (A) should result in 100% intelligibility. The SII (and ESII) at this presentation level is 0.45, which corresponds exactly to the value given as the minimum SII for acceptable intelligibility (ANSI S3.5-1997, 2007).

Neither the SII nor the ESII adequately consider listening conditions in which speech and noise sources originate from different locations. In these conditions the binaural auditory system allows one to listen selectively and improve the SRT, as discussed above. The effects of the binaural auditory system are considered by use of the HINT Composite threshold. The Composite HINT threshold equally weights the best- and worst-case listening scenarios to provide an overall estimate of the SRT across a variety of listening conditions. The published norm for the Composite SRT is 58.6 dB (A) (Soli & Wong, 2008; Vermiglio, 2008). The ESII corresponding to this level is approximately 0.25, or 0.10 units lower than the value calculated under the assumptions in the standard. These considerations suggest that the minimum ESII and SII for acceptable intelligibility is also 0.10 units lower than the value stated in the Standard, or 0.35 instead of 0.45, when best- and worst-case listening conditions are given equal consideration.

Another consideration is that effective speech communication, especially in situations where the utterances can be repeated, does not necessarily require 100% intelligibility, that is, an ESII of 0.35. For example, if an ESII corresponding to 80% intelligibility is specified, this means that 80% of the time communication is effective and 20% of the time it is not. If communication is not effective and the utterance is repeated, the likelihood that the repetition will also not be effective is also 20%, assuming the two attempted communications are independent—a conservative assumption. Thus, the joint probability that both communications will be ineffective is the product of the two probabilities of ineffective communication, or 0.20 X 0.20 = 0.04, and the probability of an effective communication after one repetition is 1.00 – 0.04 = 0.96; thus, when a single repetition is allowed nearly perfect communication can occur when the likelihood of effective speech communication without repetition is 0.80.

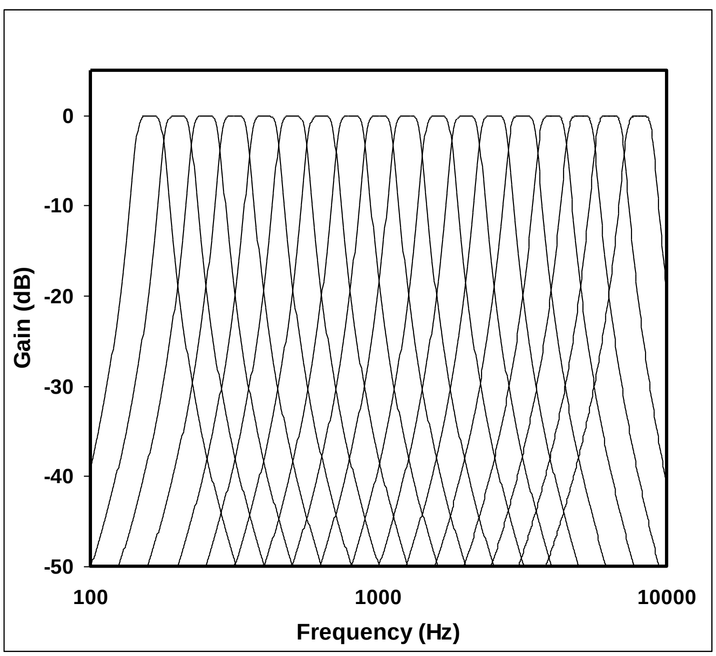
The ESII corresponding to 80% intelligibility under worst-case conditions is 0.40. If the prior reasoning that weights best- and worst-case scenarios equally is applied, the ESII value for effective speech communication is reduced by 0.10 to 0.30. Thus, an ESII of 0.30 can serve as a conservative criterion for evaluation of the 16 cumulative frequency distributions associated with each location to determine the proportion of 4-sec intervals in which the ESII exceeds the criterion value. This proportion defines the likelihood of effective speech communication in the background noise environments associated with each location. In summary, these analyses can define the likelihood that Correctional Officers with normal speech communication ability working in these locations encounter background noise environments allowing effective speech communication while performing the hearing-critical job functions of a normal work day.

Appendix K: Method for calculation of the Extended Speech Intelligibility Index

Preparation of ESII Data Sets

The SII and ESII are based on the band importance function for speech (ANSI 3.5-1997, 2007). The band importance functions specify for different frequency bands the relative importance of speech information contained in the band. The standard for calculating SII also specifies the standard speech spectrum level in each band as a function of vocal effort, which is defined as either normal, raised, loud, or shouted. The spectrum level of speech information in a band in relation to the spectrum level of noise in the same band, together with the band importance of the speech information, is used to calculate the SII. Thus, it is essential to determine the spectrum level of the noise for each band. This is done by filtering the noise recordings into a number of frequency bands. The standard specifies that one such method of filtering is to use 18 1/3 octave band filters with center frequencies ranging from 160 Hz to 8000 Hz with equal logarithmic spacing.

A 1/3 octave band filter set was designed using a Matlab program developed by Courvreur (1997). This program designs fractional octave band filters, that is, 1/3 octave band, according to specifications in ANSI S1.1-1986. The frequency responses of the 18 filters used in the current analyses are show in the Figure below. Note that all of the filters exhibit unity gain in their pass band, which is important for the use of the RMS-to-dB calibration for each band.



Frequency responses of 18 1/3 octave band filter set used to process background noise recordings for ESII calculations.

The SII does not specify the duration of the time interval over which the spectrum level of the noise in each band is to be calculated, since it assumes the noise is stationary. However, the ESII makes no such assumptions. It specifies precisely the duration for each of the 18 frequency-dependent time windows, with the windows for the lowest frequency band having the longest duration (35 ms) and the windows for the highest frequency band having the shortest duration (9.4 ms; Rhebergen & Versfeld, 2005). These windows are aligned at their offsets and are spaced every 9.4 ms, the duration of the shortest time window. This means that the windows for low frequency bands overlap substantially.

A Matlab program was written to filter each recording with the 18 1/3 octave band filters. Rectangular frequency-dependent time windows were applied to the 18 filtered time waveforms every 9.4 ms, and the RMS level for each window was calculated. This process produced slightly more than one hundred RMS values per second of recording for each of the 18 1/3 octave band filter outputs. These RMS values were converted to band levels expressed in dB SPL using the calibration information for each band described above. Next, the noise band levels were converted to noise spectrum levels by applying the bandwidth adjustment values given in Table 3 of the standard (ANSI 3.5-1997, 2007).

The noise spectrum levels for the 18 bands, expressed every 9.4 ms, together with the speech spectrum levels and the band importance function for short passages of easy material from the standard (ANSI 3.5-1997, 2007), were used to calculate slightly more than 100 SII values per second of recorded background noise. These calculations were performed with a series of Matlab programs developed by Muesch (2005) and posted on the web page for the standard (www.sii.to). The ESII specifies that these "snapshot" SII values be averaged over the time interval of interest to obtain a single estimate of the ESII for that interval (Rhebergen & Versfeld, 2005). Rather than use the entire duration of the recording as the interval of interest, it is more appropriate to define a shorter interval during which a typical brief two-way communication might occur. This interval was specified as 4 seconds Thus, the average ESII was calculated for all 4-second intervals in each recording. There are 435 SII snapshots in each 4-second interval that contribute to the average. Note that these intervals are not exactly 4 seconds in duration because there is no integer multiple of 9.4 ms whose product is exactly 4 seconds.

The ESII calculation process described in the preceding paragraph was repeated 16 times for the data from each location, using the four levels of vocal effort specified in the standard (normal, raised, loud, and shouted) and four communication distances (0.5 m, 1 m, 5 m, and 10 m).

The final step in processing the 16 ESII data sets from each location was to cast each data set into cumulative frequency distributions. Once in this form, it was possible to determine the proportion of 4-second intervals in which the ESII exceeded a specified criterion value for each level of vocal effort and each communication distance. The ESII step size for the frequency distributions was set at 0.03, which is the change in ESII corresponding to 1 dB change in SRT for an audiometrically normal individual.

Weighted Combination of ESII Data Sets

The ESII data sets from multiple locations and multiple facilities were grouped according to location. A total of 9 locations were identified as the most important locations for hearing-critical job functions. The 9 locations are as follows (in alphabetical order): control booth, chow hall, housing, kitchen, laundry and vocational, medical, receiving and releasing, visitation, and yard.

Housing was further divided into 4 types based on construction design: 270/180, dorm, tiered, and linear. Thus, a total of 12 location-specific pooled ESII data sets were formed. The number and size of data sets within a location and the number of facilities represented within a location varied in an unsystematic manner, which made the relative contribution of individual data sets to the analysis for each location also unsystematic. To address this problem, three constraints were placed on the use of data sets in the analyses of each location.

The first constraint was that no more than 5 data sets from different facilities were used in the analysis for any location. In some cases more than 5 sets were available, but their use would have meant that unequal numbers of data sets were contributed by some facilities. When more than 5 sets were available, the 5 used were selected from different facilities that had the widest range of overall noise levels.

The second constraint was on the size of the data sets, which varied by a factor of 3 or more over the selected data sets. Using the smallest selected data sets as a guide, 2 minutes of ESII data were sampled from each data set. Thus, average ESII values for 30 4-sec intervals were drawn from each data set. These 30 intervals were distributed uniformly over the entire duration of the data set. In this manner, imbalance in the representativeness of data sets due to the size of the contributing data sets and to the number of facilities represented was controlled. These controls were instituted at the expense of eliminating some of the data from the analysis; however, these data have been maintained and are available for additional analysis in the future, should the need arise.

The third constraint arose from the need to produce a single overall estimate of the likelihood of effective communication throughout the entire workday for a Correctional Officer. The amount of time in a day that a Correctional Officer spends in each of the 12 locations is not equal, and, more importantly, the nature and importance of hearing-critical tasks that occur in each location is also not equal. Thus, the contributions of each location to the overall estimate were weighted according to the amount of time and importance of hearing-critical job functions associated with each location. The overall weighted estimate provides a single composite characterization of the likelihood of effective communication during an entire workday. This estimate is based only on speech communication tasks because of the criticality and importance of these tasks to the safety of Correctional Officers and inmates, as determined from both the SME interviews and the incident reports. These three constraints were dealt with by systematically pooling the ESII data sets of different sizes from different locations and different facilities.

Appendix L: Background on the State prison system

Range of typical tasks performed by correctional officers

A sample of typical tasks Correctional Officers ordinarily perform as a part of their job is as follows (Sources: Department of Personnel Administration Job Description; CSA Job Analysis Survey, December 2007):

- Disarm, subdue, and apply restraints to an inmate
- Respond to an auditory message (by an inmate, another Correctional Officer, a radio, or a general alarm) to move to the scene of a disturbance or emergency
- Supervise inmates in housing units, during meals, and bathing
- Supervise inmates at recreation, in classrooms, and work assignments
- Escort inmates to and from activities
- Stand watch on armed posts or patrols
- Question inmates to obtain information
- Maintain visual surveillance of institutional grounds from observation tower or central security area
- Defend self against an inmate armed with a weapon
- Listen for unusual sounds that may indicate illegal activity or disturbances such as whispering, scuffling, or rattling of chain link fence
- Communicate orally with inmates or other Correctional Officers
- Search cells and conduct body searches
- Supervise and monitor visitor areas when inmates receive visits
- Use non-lethal and, if necessary, lethal force to subdue inmates
- Render aid to injured inmates and other correctional staff

The 2007 job analysis also identified equipment that was used frequently by Correctional Officers (including during the first three years on the job) and if used incorrectly would cause serious consequences. A sample of items rated as being used frequently and being critical for the position is as follows:

- Body armor (e.g., protective vests)
- Mace, tear gas or OC spray
- Personal alarm system
- Gas mask or self-contained breathing apparatus
- Telephone
- Hand-held (two-way) radio or "beeper" radio

Assignment posts

Correctional Officers work in a variety of posts (locations) within each prison as listed below. All Correctional Officers must be prepared to work at any of these posts.

- *Chow Halls*: where inmates eat their meals.
- *Control Booths:* stations accessible only to Correctional Officers allowing visual monitoring of inmates either by line of sight or by camera; and, auditory monitoring of, and communication with, inmates by shouted speech or by intercom.
- *Housing Units*: where inmates sleep; also encompasses shower and toilet areas.
- *Kitchens:* food preparation areas; food served in the Chow Halls is prepared here by inmates under the supervision of Correctional Officers.
- *Laundry:* Washers and dryers are located here to wash and dry inmate clothing, bedding, and other washable items; inmates run laundry equipment under the supervision of Correctional Officers.
- *Medical Units:* include infirmaries, medical examination rooms, nurse stations, and medication dispensing areas.
- *Towers:* observation areas at the top of raised structures providing a view of portions of the prison yards and grounds.
- *Visiting Areas:* where visitors such as family meet with inmates; areas range from booths with intercoms to large open areas with tables and chairs.
- *Vocational Areas:* manufacturing/industrial areas where products such as license plates are fabricated.
- *Yard*: large outdoor areas that may contain baseball fields, running tracks, etc.

Number of applicants and incumbents

Approximately 25,000 Correctional Officers are employed in 33 prisons located throughout California. In 2008-2009, over 6000 applicants were screened for the entry-level position and approximately 800 were hired. In the aggregate, the officers supervise over 160,000 inmates.

The prisons

The California State prisons are located throughout the state as shown below. Of the 33 prisons, 11 are in the northern region, 8 are in the central region, and 14 are in the southern region. There are three women's prisons, two in the central region and one in the southern region.